This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

GS - AU - N

HARVARD UNIVERSITY

LIBRARY

OF THE

Museum of Comparative Zoölogy

AP3 .G3 1900

DEPARTMENT OF MINES AND AGRICULTURE, SYDNEY.

RECORDS

OF THE

GEOLOGICAL SURVEY OF NEW SOUTH WALES.

VOL. VII.

1900–1904.

SYDNEY: WILLIAM APPLEGATE GULLICK GOVERNMENT PRINTER.

1905.

*65419

CONTENTS.

PAGE.

I.—The Auriferous Deposits of Lucknow, with Plate I; by E. F. PITTMAN, A.R.S.M., Government Geologist 1

II.—The Auriferous Ore-beds of the Lyndhurst Gold-field, with Plates II–V; by E. F. PITTMAN, A.R.S.M., Government Geologist 9

III.—On a Collection of Graptolites from Mandurama, with Plate VI; by T. S. HALL, M.A., Melbourne University 16

IV.—Notes upon the Occurrence of Gold in Volcanic Glass at Grassy Gully, Yalwal District, with Plate VII; by J. B. JAQUET, A.R.S.M., Geological Surveyor 17

V.—Contributions to our Knowledge of Broken Hill, with Plate VIII; by R. BECK, Professor at the School of Mines, Freiburg .. 20

VI.—An Eclogite-bearing Breccia from the Bingera Diamond Field, with Plates IX–XI; by GEORGE W. CARD, A.R.S.M., F.G.S., Curator and Mineralogist 29

VII.—Nepheline-Basalt from the Capertee Valley; by GEORGE W. CARD, A.R.S.M., F.G.S., Curator and Mineralogist 40

VIII.—Mineralogical Notes, No. 7; by GEORGE W. CARD, A.R.S.M., F.G.S., Curator and Mineralogist 43

IX.—Chemical Notes on Glaucophane Schists from Australia and New Caledonia; by H. P. WHITE, F.C.S., Assistant Analyst and Assayer 47

X.—The Graptolites of New South Wales in the Collection of the Geological Survey of New South Wales, with Plates XII–XIV; by T. S. HALL, M.A., Melbourne University 49

XI.—Notes on Fossil Leaves from the Tertiary Deposits of Wingello and Bungonia, with Plates XV–XVII; by HENRY DEANE, M.A. 59

XII.—Palæontologia Novæ Cambriæ Meridionalis—Occasional Descriptions of New South Wales Fossils, with Plate XVIII; by R. ETHERIDGE, Junr., Curator of the Australian Museum .. 66

XIII.—Notes on some large Chonetine Shells from the Carboniferous of New South Wales, with Plates XIX–XX; by W. S. DUN, Palæontologist 69

XIV.—Carboniferous Brachiopods from Clarence Town, New South Wales, with Plates XXI–XXIII; by W. S. DUN, Palæontologist 72

XV.—On *Atherstonia australis* and *Ctenolates avus*, two new species of Fossil Fishes from New South Wales, with Plate XXIV; by A. SMITH-WOODWARD, LL.D., F.L.S., British Museum .. 88

PAGE.

XVI.—Description of a new species of *Productus* from the Carboniferous System of New South Wales, with Plate XXV; by W. S. DUN, Palæontologist 91

XVII.—Analcite-bearing Rocks from the Sydney District, with Plate XXVI; by G. W. CARD, A.R.S.M., F.G.S., J. C. H. MINGAYE, F.C.S., and H. P. WHITE, F.C.S. 93

XVIII.—The Geology of the Cambewarra Mountain, New South Wales, with especial reference to the Volcanic Rocks; by GEORGE W. CARD, A.R.S.M., F.G.S., Curator and Mineralogist, and J. B. JAQUET, A.R.S.M., F.G.S., Geological Surveyor. Analyses by J. C. H. MINGAYE, F.I.C., F.C.S., Analyst to the Department, and H. P. WHITE, F.C.S., Assistant Analyst. Plates XXVII–XXX 103

XIX.—An Outline of the Tertiary History of New England; by E. C. ANDREWS, B.A., Geological Surveyor, with Plates XXXI–XLI 140

XX.—Mineralogical Notes, No. 8; by GEORGE W. CARD, A.R.S.M., F.G.S., Curator and Mineralogist, with Plates XLII–XLIV.. 217

XXI.—Notes from the Chemical Laboratory, Department of Mines; by JOHN C. H. MINGAYE, F.I.C., F.C.S., Analyst and Assayer .. 219

XXII.—Notes on the Occurrence of Monazite in the Beach Sands of the Richmond River, New South Wales; by JOHN C. H. MINGAYE, F.I.C., F.C.S., Analyst and Assayer 222

XXIII.—Notes and Analyses of Olivine-Basalt Rocks from the Sydney District, No. 1; by JOHN C. H. MINGAYE, F.C.S., F.I.C., Analyst and Assayer, and H. P. WHITE, F.C.S., Assistant Analyst 226

XXIV.—Descriptions of two new Plants from the Tertiary of New South Wales, *Pteris abbreviata* and *Gervillea darlingioides;* by HENRY DEANE, M.A., with Plates XLV and XLVI .. 231

XXV.—An Unusually large Form of *Rhizophyllum* lately discovered in New South Wales; by R. ETHERIDGE, Junr., Curator of the Australian Museum, with Plate XLVII 232

XXVI.—The Fructification of *Schizoneura australis*, Eth. fil.; by R. ETHERIDGE, Junr., Curator of the Australian Museum, with Plates XLVIII and XLIX 234

XXVII.—On the Occurrence of Nepheline in Post-Triassic Basalts of the Hawkesbury Sandstone Area; by GEORGE W. CARD, A.R.S.M., F.G.S., Curator and Mineralogist 236

XXVIII.—A Preliminary Note on the Structure of Mount Lindsay; by E. C. ANDREWS, B.A., Geological Surveyor, with Plate L .. 238

XXIX.—Notes on some of the Dykes and Volcanic Necks of the Sydney District, with observations on the Columnar Sandstone; by M. MORRISON, Field Assistant. Plates LI–LIVa 241

PAGE.

XXX.—The Geology of the New England Plateau, with special reference to the Granites of Northern New England. Part I. Physiography; by E. C. ANDREWS, B.A., Geological Surveyor. Plates LV, LVI 281

XXXI.—Analyses of Leucite Basalts, &c., and Olivine Basalts from New South Wales; by JOHN C. H. MINGAYE, F.I.C., F.C.S., Analyst, and H. P. WHITE, Assistant Analyst 301

XXXII.—Notes on, and Analyses of, the Mount Dyrring, Barraba, and Cowra Meteorites; by JOHN C. H. MINGAYE, F.I.C., F.C.S., Analyst. Plates LVII and LVIIA 305

XXXIII.—Notes and Analysis of the Mt. Browne Meteorite; by HAROLD P. WHITE, Assistant Analyst 312

XXXIV.—Sub-Reniform-ovate Leaves of *Glossopteris*, with further remarks on the attachment of its Leaves; by R. ETHERIDGE, Junr., Curator of the Australian Museum. Plates LVIII, LIX .. 315

XXXV.—Notes on some new species of Palæozoic Brachiopoda from New South Wales; by W. S. DUN, Palæontologist. Plates LX, LXI 318

XXXVI.—The Discovery of a Human Skeleton at Jenolan Caves; by R. ETHERIDGE, Junr., Curator of the Australian Museum, and O. TRICKETT, L.S., Inspector of Caves. Plates LXII and LXIII 325

INDEX.

Aboriginal Skeleton—Jenolan, 325.
Actinoconchus planosulcatus, 87.
Agnostus—Lyndhurst, 10
Aladdin's Lamp Gold-mine, 2.
Alnites latifolia, 63.
Analcite Basalt—Sydney, 93–101.
Analyses—Analcite Basalt, 97–99.
Barraba Meteorite, 309.
Cambewarra Rocks, 138
Cowra Meteorite, 312.
Eclogite, 37.
Glaucophane Schists, 48.
Leucite Basalt, 301–302.
Monchiquite, 302.
Mt. Browne Meteorite, 313.
Mt. Dyrring Meteorite, 307.
Olivine Basalt, 304.
Pyroxene, 35.
Andesites—Cambewarra Mt., 115.
ANDREWS, E. C.—An Outline of the Tertiary History of New England, p. 140; Preliminary Note on the Structure of Mount Lindsay, p. 238; The Geology of the New England Plateau, with special reference to the Granites of New England. Part I. Physiography, p. 281.
Argophyllites levis, 62.
Atherstonia australis, 89.
Athyris planosulcatus, 87.
Augite pikrite—Ruby Hill, 31.
Auriferous Deposits—Lucknow, 1.
,, ,, Lyndhurst, 9.
Azygograptus, 51.

Barraba—Meteorite, 308.
Basalt—Ruby Hill, 29
,, Cambewarra Mountains, 116.
,, Sydney District, 93–101.
BECK, R.—Contributions to our knowledge of Broken Hill, p. 20.
Bingera—Eclogite, 29–40.
Bolivia Level, 285.
,, Peneplain, 287.
Bondi—Basalt, 95.
Brachiopoda, 69–88, 318–325.
Breccia—Ruby Hill, 29.
Broken Hill—Ore Deposits, 20–28.
Bungonia—Tertiary Leaves, 65.
Burragorang—Nepheline Basalt, 236.
Byrock—Leucite Basalt, 301.

Callograptus cf. *Salteri*, 57.
Cambewarra Mt.—Geology, 103–140.
Canterbury Dyke, 93.
Capertee Valley—Nepheline Rocks, 40–43.
Capoompeta Level, 285.
Carboniferous Fossils, 69–88.
CARD, G. W.—An Eclogite-bearing Breccia from the Bingera Diamond Field, p. 29; Nepheline Basalt from the Capertee Valley, p. 40; Mineralogical Notes, No. 7, p. 43; Mineralogical Notes, No. 8, p. 217; On the Occurrence of Nepheline in Post-Triassic Basalts of the Hawkesbury Sandstone Area, p. 236.
CARD, G. W., and JAQUET, J. B.—The Geology of the Cambewarra Mountain, New South Wales, with especial reference to the Volcanic Rocks. Analyses by J. C. H. Mingaye and H. P. White, p. 103.
——— J. C. H. MINGAYE, and H. P. WHITE.—Analcite-bearing Rocks from the Sydney District, p. 93.
Cedrelophyllum antiqua, 63.
Chemical Notes, 219–221.
Chonetes aspinosa, 69–71.
„ *Culleni*, 321.
Cinnamomum Leichhardti, 64.
Clarence Town—Fossils, 72–88.
Clathrograptus cf. *geinitzianus*, 56.
Climacograptus affinis, 16.
„ *bicornis* var. *longispina*, 54.
„ *hastata*, 54.
„ *tubuliferus*, 55.
Columnar Sandstone, 264–266.
Conocardium australe, 68.
Corchorites crenulata, 62.
Cowra Meteorite, 311.
Cretaceous Peneplain, 201.
Ctenolates avus, 90.
Cyrtina wellingtonensis, 319.

DEANE, H.—Notes on Fossil Leaves from the Tertiary Deposits of Wingello and Bungonia, p. 59; Descriptions of two new Plants from the Tertiary of New South Wales, *Pteris abbreviata* and *Gervillea darlingoides*, p. 231.
Dendrograptus, 58.
Dicellograptus affinis, 51.
„ cf. *divaricatus*, 52.
„ *elegans*, 52.
Dieranograptus ziczac, var. *minimus*, 52.
Dictyonema, 57.
Dielasma hastata, 81.
„ *saccula*, 81.
Diplograptus carnei, 53.
„ *foliaceus*, 53.
„ *manduramæ*, 16.
„ cf. *Whitfieldi*, 54.
Drimys levifolia, 65
DUN, W. S.—Notes on some large Chonetine Shells from the Carboniferous of New South Wales p. 69; Carboniferous Brachiopods from Clarence Town, p. 72; Description of a new species of *Productus* from the Carboniferous of New South Wales, p. 91; Notes on some new species of Palæozoic Brachiopoda from New South Wales, p. 318.

Dundas—Olivine Basalt, 229.
Dural—Nepheline Basalt, 237.
Dykes—Cambewarra Mt., 127–131.
„ Ruby Hill, 30.
„ Sydney District, 241–281.

Eclogite—Ruby Hill, 33.
El Capitan—Leucite Basalt, 301.
ETHERIDGE, R.—Palæontologia Novæ Cambriæ Meridionalis—Occasional Descriptions of New South Wales Fossils, p. 66; An unusual large form of *Rhizophyllum* lately discovered in New South Wales, p. 232; The Fructification of *Schizoneura australis*, Eth. fil., p. 234; Sub-Reniform-ovate Leaves of *Glossopteris*, with further remarks on the attachment of its leaves, p. 315.
——— and TRICKETT, O.—The discovery of a Human Skeleton at Jenolan Caves, p. 325.

Fagus Benthami, 62.
„ *Pittmani*, 61.
Fish-Fossil, 88–91.
Fructification—*Schizoneura*, 234.

Garnet—Ruby Hill, 31, 33.
Garnet Gneiss—Broken Hill, 21.
Girvanella, 10.
Glaucophane Schist, 47–49.
Glen William Beds, 72–88.
Glossograptus mucronatus (?), 55.
Glossopteris nephroedicus, 315–318.
Good Dog Mt.,—Geology, 103–140.
Graptolites, 10, 16, 49–59.
Granites—New England, 281–300.
Grassy Gully—Gold, 17.
Grevillea darlingoides, 231.

HALL, T. S.—On a Collection of Graptolites from Mandurama, p. 16; The Graptolites of New South Wales in the Collection of the Geological Survey, p. 49.
Hartley—Fossils, 67–69.
Hawkesbury Sandstone, 117.
Human Skeleton—Jenolan, 325.

JAQUET, J. B.—Notes on the Occurrence of Gold in Volcanic Glass at Yalwal District, p. 17.
——— *Vide* CARD, G. W.
Jenolan—Skeleton, 325.
Junction Reefs—Mandurama, 11.

Kelephite, 31, 33.

Lamprophyre—Cambewarra Mountains, 119.
Leptæna analoga, 74.
„ *rhomboidalis*, 74.
Leptograptus, 51.
Leucite Basalt—Analyses, 301–304.
Litsæophyllum wingellense, 64.
Lucknow—Auriferous Deposits, 1.
Lyndhurst—Auriferous Deposits, 9.

Mandurama—Graptolites, 16.
Meristina (?) *australis*, 318.
Meteorites, 218, 305–314.
Mineralogical Notes, 43–46, 217–219.
MINGAYE, J. C. H.—Notes from the Chemical Laboratory, Department of Mines, p. 219; Notes on the Occurrence of Monazite in the Beach Sands of the Richmond River, New South Wales, p. 222; Notes and Analyses of the Mount Dyrring, Barraba, and Cowra Meteorites, p. 305.
——— and WHITE, H. P.—Notes and Analyses of Olivine-Basalt Rocks from the Sydney District, No. 1, p. 226; Analyses of Leucite Basalts, &c., and Olivine Basalts from New South Wales, p. 301.
Modiola hartleyensis, 68.
Mole Level, 286.
„ Peneplain, 288.
Monchiquite—Murrumburrah, 301.
Moorefields—Dyke, 93.
Monazite—Richmond River, 222–226.
Montanite, 221.
Mt. Browne—Meteorite, 218, 312.
Mt. Dyrring—Meteorite, 218, 305.
Mt. Lindsay, 238–240.
Mytilus Bigsbyi, 67.

Namoi River, 169, 170.
Nanima—Montanite, 221.
Narrabeen—Olivine Basalt, 228.
Nepheline Basalts, 236–238.
„ Rocks—Capertee, 40–43.
Nephelites denticulata, 65.
„ *equidentata*, 61.
„ *ovata*, 61.
New England—Physiography, 140–216, 281–300.
„ Geology, 281–300.

Obolella, 10.
Obsidianites, 218–219.
Olivine Basalts—Analyses, 226–230, 302–304.
Ordovician Graptolites, 49–59.
Orthis australis, 79.
„ *resupinata*, 78.
„ *valida*, 324.
Orthothetes crenistria, 80.

Pennant Hills—Olivine Basalt, 229.
Permo-Carboniferous—Fossils, 66–69.
„ Cambewarra, 103–140.
Persoonia propinqua, 65.
PITTMAN, E. F.—The Auriferous Deposits of Lucknow, p. 1; The Auriferous Ore-beds of the Lyndhurst Gold-fields, p. 9.
Pleurograptus, 51.
Podocarpus præcupressiformis, 65.
Productus sp., 67.
„ *barringtonensis*, 91–93.
„ *pustulosus*, 75.
„ *semireticulatus*, 77.

Prospect—Olivine Basalt, 229.
Psychotriphyllum attenuatum, 60.
Pteris abbreviatum, 231.

Red tuffs—Cambewarra, 106.
Retiolites caudatus, 56.
Reticularia lineata, 85.
„ *crebristria*, 85.
Rhipidomella australis, 79.
„ *valida*, 324.
Rhizophyllum enorme, 232–3.
Rhynchonella pleurodon, 82.
Richmond River—Monazite, 222–226.
Ruby Hill—Eclogite, 29–40.

Schizoneura australis, 234.
Schizophoria resupinata, 78.
Sills—Lyndhurst, 12.
Skeleton, Human—Jenolan, 325.
Spirifera Davidis, 323.
„ *pinguis*, 84.
„ *Pittmani*, 320.
„ *striata*, 83.
„ *tasmaniensis*, 66.
Spiriferina cristata, 86.
Stannifer Level, 286–288.
Stream Development, 146–151.
Strophalosia, 78.
Sydney District—Dykes, 241–281.
Syringothyris exsuperaus, 86.

Tertiary History—New England, 140–216.
Tertiary Leaves, 59–66, 231–232.
Trachyte—Cambewarra, 109.
TRICKETT, O.—*Vide* ETHERIDGE, R.
Tuffs—Lyndhurst, 12.

Vanadium in Coals, 219.

Wentworth Gold-fields, 2.
WHITE, H. P.—Chemical Notes on Glaucophane Schists from Australia and New Caledonia, p. 47; Notes and Analysis of the Mt. Browne Meteorite, p. 312.
———*Vide* CARD, G. W., and MINGAYE, J. C. H.
———*Vide* MINGAYE, J. C. H.
Wingello—Tertiary Leaves, 59.
WOODWARD, A. S.—On *Atherstonia australis* and *Ctenolates avus*, two new species of Fossil Fishes from New South Wales, p. 88.

Yalwal—Gold, 17.

Corrigenda.

Page 281, line 23. For *cycle* read *period.*
Page 282, line 4. For *early* read *middle.*
Page 283, line 21. For *cycle* read *period.*
Page 283, line 27. For *cycle* read *period.*
Page 285, line 2. For *J. Curran* read *J. P. Curran.*
Page 286, line 22. For *cycle* read *period.*
Page 286, line 27. For *cycle* read *period.*
Page 288, line 18. For *cycle* read *period*
Page 288, line 32. Insert (Pl. LVI).
Page 290, line 2. For *cycle* read *period.*
Page 291, line 2. For *cycle* read *period.*
Page 292, line 6. For *cycle* read *period.*
Page 292, line 7. For *cycle* read *period.*
Page 292, line 11. For *strains* read *streams.*
Page 293, line 18. For *cycle* read *period.*
Page 296, line 7. For *cycle* read *division.*
Page 297, line 37. For *cycle* read *period.*
Page 297, line 37. For *period* read *cycle.*
Page 300, line 14. For *accomplished by subsistence* read *accompanied by subsidence.*

DEPARTMENT OF MINES AND AGRICULTURE, SYDNEY.

RECORDS

OF THE

GEOLOGICAL SURVEY OF NEW SOUTH WALES.

Vol. VII.] OCTOBER, 1900. [Part 1.

I.—The Auriferous Deposits of Lucknow: by E. F. PITTMAN, A.R.S.M., Government Geologist.

[Plate I.]

THE rich auriferous deposits which have been worked in the Wentworth group of mines at Lucknow, about six miles from the town of Orange, on the Great Western Railway, are unique, both in their mode of occurrence and in regard to the character and appearance of the ore; so characteristic, indeed, is the latter, that it can be distinguished, almost at a glance, from any other auriferous ore in Australia.

Alluvial gold was first found at this locality about the year 1863, when a shallow (Pleistocene) deposit of considerable richness was worked. Subsequently a Tertiary (Pliocene) *lead* was discovered under a flow of basalt, and proved payable for a distance of about half-a-mile; the returns from this *lead* are said to have been from one to five ounces of gold per load.

The sources, from which these detrital deposits were derived, were afterwards worked in a number of claims, from which surprisingly rich yields were obtained in a very short time; thus, according to the Mining Warden's report, the claim on the Golden Point Vein yielded to its shareholders £50,000 worth of gold in nine months; Spicer's Vein, within a length of eighty feet, yielded £42,000 in six months; the Golden Gate Vein, within a similar length, yielded £35,000 in eight months; £30,000 worth of gold was obtained in two years from the Shamrock Vein, within a length of eighty feet; within a distance of twenty feet, on the Crinoline Vein, £20,000 worth of the precious metal was recovered in eighteen months; and a yield of the value of £20,000 was obtained in one year from eighty feet of Snob's Vein. These extremely rich deposits of gold, or "bonanzas" as they were called, were separated, both horizontally and vertically, by considerable distances of barren ground, and, owing to their mode of occurrence not having been properly understood at this time, the miners failed to seek for their recurrence at a depth, and in many cases abandoned their claims when the first rich deposits were worked out.

In December, 1881, the New Reform Gold Mining Company was formed to work an area of twelve acres, containing seven of these veins. This company were successful in obtaining some exceedingly rich bonanzas, and during the years 1885–86 they paid the sum of £17,750 in dividends, after clearing off all expenses connected with the purchase of machinery, and sinking their main shaft to a depth of four hundred feet. In the year 1887 the company won gold to the value of £15,326; in the following year the workings reached a depth of five hundred and twenty-five feet, and three thousand tons of ore, valued at £6,484, were raised. In 1889 no rich deposits were found, and the property was for sale. It was realised that the appliances at hand were inadequate for the economic winning and treatment of the refractory ore occurring in the deeper levels, and that the mine could only be satisfactorily worked by a company with a considerable amount of capital.

In December, 1890, an area of one thousand and thirty-three acres, including the Reform Mine, the New Reform Pups, and the other veins previously worked in small claims, was acquired by the Wentworth Gold-fields Proprietary Company (Limited), with a capital of £500,000, and in June, 1892, a subsidiary company, called the "Aladdin's Lamp Gold-mining Company," with a capital of £100,000, was formed to work thirty-eight acres of the previously mentioned area.

There is no doubt that the Wentworth Gold-fields Proprietary Company was largely over-capitalised, as only a comparatively small portion of their enormous area contained payable auriferous deposits, and in view of the isolated character of the rich auriferous deposits (the mode of occurrence of which will be presently described) and the expensive "dead work" which is a necessity during the operations of prospecting for new bonanzas, it was hopeless to expect that the mine could continue to pay interest upon such an enormous nominal capital.

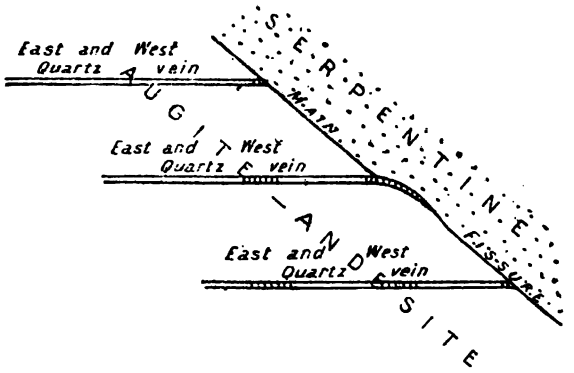
Vigorous prospecting was commenced after the formation of the company, resulting very shortly in the discovery of extremely rich deposits of gold, as the returns which are appended will show:—

RETURN showing ore won and gold obtained from the Wentworth Gold-fields Proprietary and Aladdin's Lamp Mines, from 1892 to 1899 inclusive.

Year.	Wentworth Gold-fields Proprietary.			Aladdin's Lamp Company.		
	Tons of ore.	Ounces of gold.	Value.	Tons of ore.	Ounces of gold.	Value.
			£			£
1892	.....	8,264½	31,358	.....	10,436	38,309
1893	10,000	8,992	35,262	2,500	5,636	21,966
1894	10,947	19,992	72,118	4,298	14,008	47,645
1895	9,381	58,100	203,350	3,889	23,078	80,773
1896	9,368	12,048	42,564	3,052	16,718	58,195
1897	6,225	5,281	18,752	3,027	6,064	20,710
1898	10,870	17,600	61,600	4,866	7,344	22,032
1899	6,434	3,956½	14,572	6,605	7,185½	26,603
	63,225	134,234	479,576	28,237	90,469½	316,233

Description of the deposits.

The mode of occurrence of the rich deposits of auriferous ore in these mines is extremely interesting. They are found invariably under the same conditions, viz., as shoots, pipes, or bunches of ore at or near the junctions of a number of east and west veins with a main fissure whose general direction or strike is north-west and south-east. The main fissure is vertical in some places, and nearly horizontal in others, but it has a general dip to the north-east at an average angle of sixty degrees. It is known locally as "the lode" or "the joint," and some writers have asserted that it is neither a lode nor a fissure. The term "lode" is doubtless somewhat misleading, inasmuch as the ore-bodies only occur at or near where the east and west veins junction with it, and elsewhere the walls are contiguous to one another, forming a mere plane of section. Nevertheless there is abundant evidence in the mine to show that it has been a genuine fissure, for numerous striated slickensides (in some cases having a polished surface of stibnite) supply proof of movements of the hanging wall after the fracture had taken place, and distinct faults are also visible in it in places.. No evidence, however, appears to exist of its having thrown, or been thrown by, the east and west veins.



Sketch plan showing mode of occurrence of ore bodies in the Lucknow Mines.
||||||| Ore bodies.

The rock forming the north-eastern or hanging wall of the main fissure in those places where the productive deposits occur, is a mottled dark-green and white serpentine, while the south-western or foot-wall is formed of a greenish-gray augite-andesite, locally termed diorite. Occasionally the augite crystals impart to this rock a porphyritic structure on a small scale. Where the andesite forms the hanging wall of the main fissure it often exhibits the effects of crushing.

It seems to be an invariable rule in this mine that deposits of auriferous ore only occur where serpentine forms the hanging-wall of the main fissure; where both walls of the fissure are composed of andesite there is no ore body. Occasionally rounded masses of hard rock, termed "boulders" by the miners, are found imbedded in the serpentine of the hanging-wall; these are easily separated from the enclosing rock, and are of various sizes, from a few inches up to many feet in

diameter. They have a skin or coating of serpentine on the outside, but on being broken they are seen to consist of the same rock as that forming the foot wall of the fissure, viz., augite-andesite.

Some little distance to the north-east of the serpentine the latter is again succeeded by augite-andesite; in short, the serpentine forms a narrow lenticular belt, about three hundred feet in its maximum width, bounded on its south-western side by the main fissure, which also separates it from the andesite.

This remarkably sharp boundary between the two formations, when considered in conjunction with the occurrence of the round masses ("boulders") of andesite imbedded in serpentine, naturally suggests the idea that the serpentine has been derived from the decomposition of the augite-andesite. A microscopic examination of thin slices of a number of specimens of rock, from both the hanging and foot walls of the fissure, has lately been made by Professor David, and fully bears out this assumption. In many cases the porphyritic crystals of augite show, under the microscope, every stage of passage from a condition of unaltered pyroxene into pseudomorphs of serpentine. Similar evidence was obtained from thin slices of the hard rock forming one of the rounded masses or "boulders." An apparently homogeneous rock of dark colour, which is termed "black rock" by the miners, and which is sometimes found between the typical serpentine and the andesite, is seen, under the microscope, to consist of dense serpentine. An extremely hard and tough rock of a light greenish-gray colour, which has received the name of "old man" from the miners, consists of nephrite or jade. This rock only occurs where there is an ore-body, and is then found, a foot or more in width, between the ore and the hanging wall of serpentine.

The east and west veins come in from the westward and junction with the main fissure, but never, under any circumstances, continue across it. Altogether seventeen of these veins have been found, and they have been given distinctive names, such as the "Welcome," the "Homeward Bound," the "Surprise," the "Perseverance," &c. They are generally either vertical or inclined at a high angle, and they vary in width from a few inches up to six feet, or occasionally ten or fifteen feet. They have usually a more or less banded structure, and the filling is principally quartz (with included lenticular masses of augite-andesite) until they approach the main fissure, when the quartz gives place to calcite, which invariably carries the rich auriferous ore in the vicinity of serpentine. In the upper workings of the mine (above the two hundred feet level) the quartz is said to have contained much gold in the free state, but in the lower levels the gold is never, under any circumstances, found in payable quantities in a quartz gangue, but invariably (both in the free state, and as auriferous mispickel) with calcite.

There is no known instance, in the mine, of an auriferous ore-body which was not connected with one of these east and west veins, and, as already stated, the ore is found either at or near the junction of the vein with the main fissure. In

consequence of this fact very few of the east and west veins have been explored for any great distance from the junction, as the quartz only contains a very small proportion of gold (probably about two pennyweights per ton); but in one instance, viz., in the "Homeward Bound" vein, at the four hundred feet level, three distinct shoots of calcite, containing rich ore, were found and extracted. One of these was, as usual, at the junction, while the other two were in the "Homeward Bound" (east and west) vein, separated by barren areas of quartz, the third shoot being situated two hundred and forty feet from the main fissure.

Below the six hundred feet-level what are termed "droppers" are of frequent occurrence in the vicinity of the main fissure. These are irregular offshoots from the rich ore-bodies, extending downwards, in the andesite, from the footwall; they vary in length from a few feet up to fifty or sixty feet. They are similar in composition to the rich ore-bodies to which they form extensions, consisting of auriferous mispickel in a calcite gangue, though sometimes the main ore-bodies are found to be impoverished near where the "droppers" occur. In one instance (Surprise vein) a second "dropper" was found as an offshoot from the first.

When the hanging wall of the main fissure, at its junction with an east and west vein, is not composed of serpentine, there is an absence of ore, and whenever calcite is found in the fissure, with andesite forming both walls, no ore occurs in it. In the unoxidised zone, therefore, auriferous deposits are only found, in this remarkable mine, under the following conditions, viz.:—

(1.) at or near the junction of an east and west vein with the main fissure;
(2.) when serpentine forms the hanging wall of the main fissure; and
(3.) when the gangue consists of calcite.

Again the ore-bodies occur in four ways, viz.:—

(1.) as shoots or pipes along the junction of the quartz veins with the main fissure;
(2.) as bunches extending horizontally along the main fissure for a length of from twenty to fifty feet, but always starting from the toe of a quartz vein;
(3.) as "droppers" from the footwall of the main fissure;
(4.) as shoots in the east and west veins (near their junction with the main fissure), where calcite replaces the quartz for some short distance.

Character of the ore.

In the upper levels the gold was in the free state, associated with quartz, ferruginous sandy clay, and yellowish brown siliceous accretions, locally termed "clinkers," but in the unoxidised zone it is contained principally in extremely rich arsenical pyrites (mispickel), with which metallic antimony is generally (and

stibnite occasionally) associated. Iron pyrites is often present in small quantities, and in the lower levels pyrrhotine sometimes replaces the mispickel; in such cases there is a corresponding falling off in the gold contents. It is characteristic of the mispickel that it occurs in masses, from half-an-inch upwards in diameter, of beautiful stellate or radiating crystals; these starlike masses are known by the miners as "Prince of Wales feathers." The mispickel is generally extremely rich in gold, the clean mineral containing at the rate of from fifty to five hundred ounces per ton. Where free gold is associated with the arsenical pyrites the values are, of course, much higher; thus a specimen presented to the Geological Museum by Mr. C. G. Warnford Lock, the late superintendent of the mines, yielded by assay at the rate of sixteen thousand five hundred and ten ounces of gold bullion per ton. (The gold is alloyed with some silver, and the bullion is worth about £3 10s. per ounce.)

Extent of the workings.

The main fissure has been driven upon, at various levels, for a continuous length of four thousand feet, which represents a considerable amount of expensive "dead work" between the successive east and west veins, as the andesite is a very hard and tough rock, though it requires little or no timbering. The mine has been an exceedingly expensive one to prospect, both by reason of the irregularity and capricious nature of the ore deposits, and on account of the difficulty in following the main fissure, as parallel "false joints" are often mistaken for it. Some extremely rich shoots or "bonanzas" were met with at depths of from five hundred to seven hundred feet. Thus, in the "Welcome" stopes, at the five hundred feet level, the ore body was from seven to eight feet wide, half of it consisting of clean mispickel, with free gold, and the full width averaging about fifty ounces per ton. Over two tons weight of gold bullion were obtained here within a few weeks. In the "Welcome" vein, near its junction with the main fissure, at a depth of seven hundred feet, a fine body of ore was found, ten feet wide and fifty feet long, averaging about fifty ounces of gold per ton. Fifty feet below this the ore body pinched out completely (though the quartz vein continued), and there was no serpentine to be seen on the wall of the main fissure. Up to the present time no ore bodies have been discovered below a depth of seven hundred and eighty feet. At the eight hundred feet-level the junction of the "Surprise" vein has been found where there is no serpentine and no ore. Similar conditions occur at the junction of the "Welcome" vein at the same level. The greatest depth yet attained in the mine is one thousand feet, where the only vein hitherto struck is supposed to be the "Homeward Bound," and this has thinned out and split into four small strings, which do not reach the fissure by fifty or sixty feet. They do not contain any ore, nor is there any serpentine on the hanging wall of what is supposed to be the main fissure at this level. Owing to the

apparent absence of ore, or of the conditions which usually accompany ore, in the deeper levels, it is understood that the officials of the mine are inclined to take a gloomy view of its future prospects. It must be borne in mind, however, that this property has been justly termed "a mine of surprises," and it is reasonable to expect that other rich deposits will be found at much greater depths than have hitherto been attained. There is no certainty that the true main fissure has been found at the one thousand feet-level, and there is plenty of room to have missed it in the unprospected ground. The adjoining land on the north-east is held by the D'Arcy Estates Gold Mining Company, who have sunk a vertical shaft to a depth of one thousand feet without meeting with any considerable body of ore. Mining operations have been stopped for a considerable time, but it is understood that fresh capital has now been provided, and prospecting is about to be continued. Should any success be met with in the deep ground, it would give encouragement to the directors of the Wentworth Mine to continue to develop their property.

Depths of principal shafts.

The Jackass shaft.—This is a vertical shaft, five hundred and ninety-one feet deep, or, including the sump, six hundred and five feet.

The Phœnix shaft, inclined at an angle of 40° 20′, has a depth of one thousand one hundred feet, which is equal to seven hundred and twelve feet vertical.

The Reform shaft is vertical for three hundred and ninety-four feet, below which an inclined winze extends at an angle of sixty-six and a half degrees for a distance of two hundred and sixteen feet, reaching a total vertical depth of five hundred and ninety-two feet.

The main shaft is vertical and is eight hundred and sixty feet in depth. An inclined winze from the eight hundred feet level extends to a depth of one thousand feet (vertical) from the surface.

Genesis of the ore deposits.

It is impossible to speak with any certainty as to the exact mode of origin of these extremely interesting deposits, but the conditions under which they occur are so constant that their significance cannot be overlooked in any attempt to trace the gold to its source. With regard to the formation of the ore-bodies along the main fissure, the evidence obtained from the deep workings, so far as it goes, appears to favour Sandberger's theory of lateral secretion. There is no difficulty in accounting for the presence of sulphides and arsenides in the ore-bodies, as small crystals of pyrites and mispickel are disseminated through the augite-andesite, and in the same way the calcite forming the gangue may be presumed to have been derived from the decomposition of the crystals of augite and other lime-bearing minerals in the same rock. From the fact that the

auriferous ore is always found either in contact with the serpentine, or but a short distance from it, and connected with it by fissure veins, there seems to be strong reason for directly connecting this rock with the origin of the gold deposits. It seems probable that the history of the deposits is as follows:—The decomposition of a belt of augite-andesite, with the consequent formation of serpentine, took place before the formation of the fissures, though the exact cause of the decomposition of this particular belt is not clear. Subsequently, owing to earth movements, fissuring took place, the main fracture following the line of least resistance, viz., the boundary between the serpentine and the solid andesite, while the cross open fissures occurred at intervals on the south-western side of this line, the direction of all of them being approximately parallel. Ascending hydrothermal solutions having obtained access to these cross fissures, they gradually became filled with depositions of quartz, alternating with lenticular masses of andesite which fell from the walls, thus imparting to the veins their banded appearance. But during this gradual process the hydrothermal solutions also percolated through the joints of the serpentine, dissolving lime from the decomposed augites, probably taking the gold from the same source, and sulphides and arsenides from the minute crystals of pyrites scattered through the rock. Finally, these solutions found their way laterally to the only existing cavities, viz., where the east and west open fissures junctioned with the main fissure, and there, under normal conditions of atmospheric pressure, they deposited the ore-bodies, consisting of auriferous mispickel in a gangue of calcite.

Local treatment of the ore.

The only treatment to which the ore is subjected at the mine consists of reduction and concentration, the products being classed as "firsts," "seconds," and "tailings." The battery, which is furnished with rock-breakers and automatic feeders, contains thirty-five stamps weighing eight hundred and fifty pounds each. They have a drop of six and a half inches, and with a speed of ninety-six strokes per minute the stamp duty is one and three-quarters of a ton per twenty-four hours; the depth of discharge is four inches, and the gratings are of nine hundred mesh. This battery deals with the ore from both the Wentworth Gold Fields Proprietary and the Aladdin Mines. What are termed "firsts" are obtained from hand-picked and very rich ore; this is put through a five-head battery, and the free gold is saved on the amalgamated copper-plates and in the stamper-box; the remaining portion of the crushed material (constituting "firsts") is run off the tables into a tank and sold to the Dapto Smelting Works on assay. It yields from thirty to five hundred ounces of gold bullion per ton.

The "seconds" are obtained by concentration from the ore forming the bulk of the deposits after the richer portions, or "firsts," have been removed by hand-picking. This ore is crushed in the battery, and, here again, the free gold is

retained in the boxes and on the plates; the pulp then passes on to Frue vanners, of which there are fourteen in the mill. The concentrates from the vanners ("seconds") contain from five to seventy ounces of gold bullion per ton; they also are sold to the Dapto Smelting Works on the basis of their assay value. The tailings and slimes are collected in a heap which, at present, is estimated to contain about sixty thousand tons, carrying from five to eight pennyweights of gold per ton. It is intended to treat these tailings by the cyanide process; but the treatment has not been successfully demonstrated as yet, owing to the difficulty of getting the slimes to settle in the vats. It is probable, however, that this will be overcome by the use of filter presses, or by subjecting the tailings to a slight preliminary roast.

II.—The Auriferous Ore-beds of the Lyndhurst Goldfield; by E. F. PITTMAN, A.R.S.M., Government Geologist.

[Plates II-V.]

SOME of the most remarkable auriferous deposits in New South Wales are situated on the Belubula River, in the parishes of Lyndhurst and Belubula, county of Bathurst, about eight miles west by south from the town of Carcoar.

The geological formation here consists of a series of banded sedimentary rocks, consisting of indurated bluish-gray claystones, alternating with intercalated ore-bodies composed of a highly altered rock, containing bunches and impregnations of auriferous mispickel, pyrrhotine, and iron pyrites. This sedimentary series has been intruded by hornblendic granite, and also by dykes and sills of diorite, apparently offshoots from the granite massif; there is also another series of dykes consisting of augite-andesite.

The deposits bear a most striking resemblance in their general appearance and mode of occurrence to the banded claystones and tuffs of the Tamworth Common (distant over two hundred miles to the north-east), and the analogy is further emphasised by the occurrence at both localities of radiolaria in the claystones, and by the presence in the Lyndhurst ore-bodies of occasional small lenticular

masses of dark bluish-gray limestone, identical in appearance and character with the masses of limestone which form so typical a feature of the Tamworth tuffaceous beds.

Radiolaria are very plentiful in these limestones at Tamworth (where they were first recognised by Professor David), and they also occur in those at Lyndhurst, although not in such a perfect state of preservation as at Tamworth.

The Tamworth tuffs and claystones, however, are associated with massive beds of limestone containing corals identical with those occurring in the Burdekin beds of Queensland, and they are, therefore, considered to be of Devonian age; the Lyndhurst claystones, on the other hand, contain fossils which indicate that these deposits are certainly not newer than Lower Silurian. Associated with the radiolaria the author has found trilobites (apparently *Agnostus*), bivalve shells (probably *Obolella*), and graptolites (*Diplograptus* and *Climacograptus*). The graptolites are very numerous in a dark bluish-gray shale. Several specimens were forwarded to Mr. T. S. Hall, of the Melbourne University, who has been kind enough to make a careful examination of them. He has described two of them as new species, and his description and illustrations are published in this number of the "Records."

It is also interesting to notice that distinct *girvanella* structure was recently recognised by Mr. G. W. Card, A.R.S.M., while making a microscopic examination of a thin slice of one of the ore-bodies.

The claystone beds and ore-bodies at Lyndhurst vary in thickness from that of a sheet of paper up to twenty feet. In places the recurrence of extremely thin beds, differing in material and colour, has resulted in the formation of a banded rock of remarkable regularity, and which cannot be distinguished from the banded rocks (tuffs and claystones) of Tamworth. The dip of the Lyndhurst beds is variable and undulating, and the surface configuration of the hills, due to atmospheric denudation, accords, in a majority of cases, with the inclination of the bedding planes of the strata. The lines of junction between the ore-bodies and the claystones present features which appear to point to the conclusion that the former have intruded the latter. This is particularly noticeable in the very thin beds of the banded rocks, where the bands of claystone have frequently been broken, faulted, and apparently in some cases partly absorbed by the ore-bodies. Precisely similar phenomena are common in the Tamworth series, where the tuffs present all the appearances of having intruded the claystones while the latter were still in a plastic condition. Within a depth of from twenty to forty feet from the surface the ore-bodies at Lyndhurst have been very much decomposed,

Photographed by E. F. Pittman.

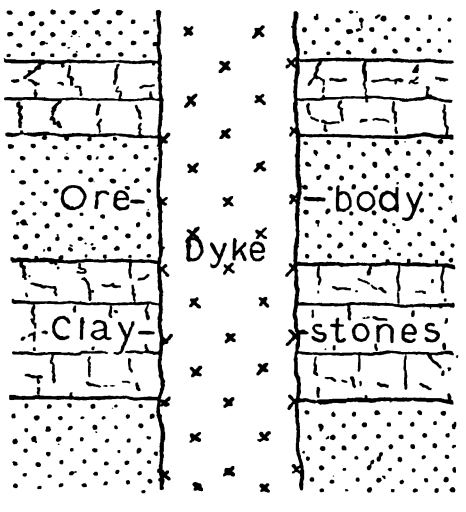
Character of the ore-bodies and intercalated claystones, Lyndhurst Gold-field.

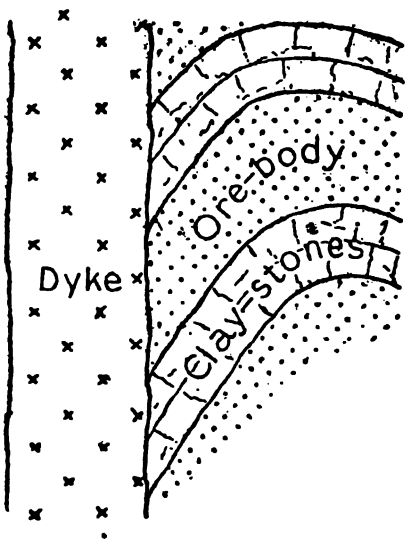
and now consist of friable gossanous material containing free gold, while the claystones have weathered to a pale yellowish-white colour, and, in some cases, have the appearance of thin beds of kaolin.

These ore-bodies were worked for gold quite twenty years ago in three mines situated within half a mile of one another, and known as "The Junction Reefs," "The Frenchman's," and "The Cornishman's," respectively. Some very rich deposits of gold were obtained from the former, and were doubtless derived from the decomposition of the auriferous sulphides. Mining operations were, however, confined to the oxidised portions of the deposits during the earlier periods of the mines' history, no attempt being made to treat the undecomposed ore-bodies; the rich gold only occurred in patches, while the bulk of the gossan was of low grade, and as it was not considered probable that the pyritous ore would pay for extraction, the excavations were not carried to any great depth. In all three mines the productive ore-bodies were intersected by dykes of diorite and augite-andesite, and there are good reasons, therefore, for concluding that the enrichment of the ore-bodies was due to the influence of these intrusive rocks.

The structure of the ore-bodies has been so much changed, apparently by the influence of hydrothermal solutions, that it is a matter of great difficulty to determine what their original components were. Their interstitial spaces and joints have been filled by secondary silica and calcite, and, as already stated, they have been largely impregnated with auriferous sulphides, such as mispickel, pyrrhotine, and iron pyrites.

The evidence of intrusion which is supplied by their junction with the claystones, both on their upper and lower surfaces, would, at first sight, suggest that they had originally been formed as sills or intrusive sheets, which, as off-shoots from the diorite or andesite dykes, had been thrust in between the bedding planes of the claystones. On the other hand, this supposition is upset by the manner in which the ore-bodies are found to junction with the dykes. Wherever one of them is seen in contact with a dyke, it is noticeable that the two are not continuous at the junction, but there is a distinct wall or plane of division between them, and there is a striking difference in the appearance and composition of the two rocks; in short, the evidence is in favour of the dykes being of more recent age than the ore-bodies.





Occasionally the ore-bodies and claystones are seen to bend downwards at their junction with the dykes, as is so often the case where sedimentary rocks are intruded from below by igneous dykes. Moreover, although there are some undoubted sills at Lyndhurst, they are distinct, in their mode of occurrence as well as in their composition, from the ore-bodies.

In the bed of the Belubula River, opposite the old "Cornishman's" Mine, a number of fine examples of intrusive sills occur. They branch off from the main diorite dyke, which trends across the field in a N.N.W. and S.S.E. direction, and they are distinctly hornblendic in character, numerous crystals of hornblende being visible in them to the naked eye. They have an uninterrupted junction with the parent dyke, and they vary in thickness from a few inches up to as much as fifty feet. Even the smallest sills, however, have produced most remarkable contact metamorphism of the overlying and the underlying strata. An extremely hard, white, cherty rock has resulted from its influence, crystals of garnet have been formed, and at the actual line of contact the rock has been fused, so that the diorite and chert appear to pass insensibly into one another.

Now, in the case of the ore-bodies, although they appear as if they had intruded the claystones, and the actual line of contact is irregular, there is no gradual passage of one rock into the other, the material of the two being always distinct; moreover, although the claystones are much indurated, they show no evidence of actual contact metamorphism similar to that described above, and which might have been expected if the ore-bodies had originally been intrusive sills; for it must be borne in mind that some of the ore-bodies are as much as twenty feet in thickness, and that they have been proved to extend for a horizontal distance of at least half-a-mile.

Probable origin of the Lyndhurst ore-bodies.

In view of the remarkable analogy which exists between these deposits and the banded rocks of the Tamworth section, there seem to be strong reasons for the assumption that they have had a similar origin. The Tamworth series, as already stated, consists of alternate beds of tuff and claystone. There are in the Lyndhurst series undoubted beds of tuff also, some of them resembling a very coarse conglomerate and containing pebbles or rounded masses of claystone several

Photographed by E. F. Pittman.

Example of coarse volcanic tuff from Lyndhurst Gold-field.

(The dark rounded fragments are composed of indurated claystone; the lighter matrix consists of tuffaceous material, containing felspars and lapilli of various volcanic rocks.)

Photographed by E. F. Pittman.

Example of *intrusive tuff* from Lyndhurst Gold-field.

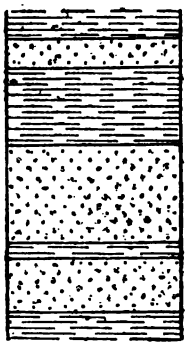
(The dark angular fragments are composed of indurated claystone; the lighter portions consist of volcanic tuff containing felspars and lapilli of various volcanic rocks.)

inches in diameter, while in others again the included fragments of claystone are exceedingly angular, and appear to be the remains of beds of claystone which have been intruded and broken up by the tuffaceous matrix through which they are now scattered.

Taking all the evidence into consideration, it would appear as if the ore-bodies at Lyndhurst had also, originally, been porous submarine tuffs, which were laid down contemporaneously with beds of mud (now forming claystones) during intermittent periods of intense volcanic activity; that while these tuffs and claystones were still in a more or less plastic condition they were subjected to much disturbance from the injection of steam and other gases, which caused the intercalated beds of tuff to intrude, break up, and, in places, envelop isolated portions of the claystone. Subsequently there was an intrusion of hornblendic granite, while offshoots therefrom in the shape of dykes and sills of diorite and augite-andesite intersected the sedimentary series in all directions. These intrusions produced induration of the claystones, while the more porous tuffs were permeated by hydrothermal solutions, which had the effect of almost entirely obliterating their original structure, while filling their interstices and joints with depositions of calcite and secondary silica, and with bunches and impregnations of auriferous sulphides and arsenides.

Extent of the auriferous deposits.

At the present time about five hundred acres of these deposits, including the three old mines ("Junction," "Cornishman's," and "Frenchman's") are held by a company known as the Lyndhurst Gold-field (Limited). Only three beds or ore-bodies have as yet been prospected by the company, and these are represented in the following section, though their thickness varies to a considerable extent in different parts of the field.



Top bed or ore-body	6 feet thick.
Claystone	15 ,, ,,
Middle bed or ore-body ...	10–20 ,, ,,
Claystone	3 ,, ,,
Lower bed or ore-body.....	11 ,, ,,

Although all three bodies were extensively worked in the old "Junction," "Cornishman's," and "Frenchman's" Mines, where they occurred in a very decomposed state, and where the gold, in consequence of its having been set free

from the sulphides, was easy of extraction, in the newer workings of the company, where the ore is in an undecomposed condition, attention has been devoted principally to the middle ore-body. A number of drives and crosscuts has been excavated in the lower six feet of this bed—the upper portion being said to be poorer—chiefly with the object of opening up and systematically prospecting the deposit; and, according to the statement of the underground manager, the ore has been found to vary in assay value from three pennyweights to over two ounces of gold per ton. Very little prospecting has been done in the other beds, but what evidence is available appears to show that the ore contained in them is of nearly equal value.

It seems probable that the enrichment of the ore-bodies is due to the intrusion of the igneous dykes and sills, for all the payable deposits hitherto worked have been in the immediate neighbourhood of these intrusions; and if this supposition be correct, it is reasonable to expect that the beds will become impoverished as they are followed to a distance from the intrusive rocks. All the workings have hitherto been confined to three comparatively restricted areas, for the excavations made by the present company are situated close to the old "Cornishman's" Mine; and although igneous dykes have been found intersecting all the ground recently opened up, it is not known to what distance they extend, and the prospecting operations of the Lyndhurst Gold Field, Limited, will therefore be awaited with interest. In the meanwhile, however, it may be stated that fairly large ore reserves have been developed.

The Reduction Plant.

The company possess a magnificent dam in the Belubula River, providing a practically unlimited supply of water-power for reduction and concentration purposes. The retaining wall is of concrete, backed by six massive arches of brickwork. The dam is situated at an altitude of about two hundred feet above the crushing mill; the water, which is conducted to the mill in fifteen-inch steel pipes, is used to drive Pelton wheels, by which all the machinery (including battery, air-compressing plant for rock-drills, and electric lighting plant) is actuated. The one pipe line provides about three hundred horse-power.

The battery is fitted with rock-breakers and automatic feeders; there are thirty-five stamps of eight hundred pounds each, which are driven at the rate of eighty-five blows per minute. The depth of discharge is one inch, with new dies, and screens of one hundred and forty holes to the square inch have been employed. A stamp duty of two tons per twenty-four hours has been obtained. It may be said, however, that hitherto the work performed at the mill has been rather of an experimental nature, and the best method of treating the ore has, perhaps, not yet been decided on. The plant is also provided with ten Lührig and four Woodbury vanners, and the latter have been found most suitable for the class of ore which

Photographed by E. F. Pittman.

Dam on the Belubula River, the property of the Lyndhurst Gold-field, Limited.

has to be treated here. There are four Pelton wheels, the three largest having diameters of six, four, and three feet respectively, while the fourth is a small Pelton motor for generating the electric light.

It was at first attempted to treat the roasted concentrates by the chlorination process, but this proved a failure owing to the large amount of lime contained in the ore. At the present time the concentrates from the vanners are carted to Burnt Yards, four miles distant, where the company's experimental cyanide plant is situated. Very cheap and efficient roasting is here performed in an Edwards' furnace with a capacity of about fifty-five tons of raw concentrates per week. This furnace is fifty-five feet long and eight feet wide, and is encased by iron plates. The concentrates are fed into the upper end by an automatic feeder, and are worked forwards, along the slightly sloping bottom, by fourteen series of rabbles which revolve on vertical axes protected by water-jackets. The roasted ore is pushed out of a hole in the bottom by the last rabbles, and is conveyed by a traveller to the cyanide vats. The roasted concentrates appear to be very suitable for treatment by the cyanide process, and some very good percentage extractions of gold have been obtained. It appears, however, as a result of the experimental operations hitherto carried out at the mill, that there is little or no free gold in the undecomposed ore. There is, therefore, nothing to be gained by passing the pulp over amalgamated copper plates, or, possibly, even over vanners, and it is probable that the most satisfactory method of treatment will yet be found to consist of dry crushing, roasting, and cyaniding. The expense saved by omitting the intermediate processes of amalgamation and concentration would be considerable, and there is no apparent reason why the cyanide treatment should not be as effective upon the ore as upon the concentrates. For the sake of economy this treatment would, of course, be all carried out at the mill, in proximity to the mine.

Quality of the ore.

The following battery returns represent the work done during the latter half of the year 1899, and will serve to give an approximate idea of the quality of the ore in the present workings:—

Period.	Ore crushed.		Concentrates obtained.		Vanner tailings.
	Tons.	Average assay value (gold) per ton.	Tons.	Average assay value (gold) per ton.	Average assay value (gold) per ton.
1899.		oz. dwt. gr.		oz. dwt. gr.	oz. dwt. gr.
July	638	0 15 18	180	1 19 13	0 7 7
August	660	0 16 11	249	1 12 0	.....
September	927	0 17 5	98	2 3 23	.....
October	845	0 13 6	90	2 0 14	....
November	...	0 7 19	...	1 4 0	0 4 0
December	...	0 13 12	...	1 5 0	0 7 0

The average assay of all the ore crushed during the six months was 14 dwt. of fine gold per ton.

III.—On a Collection of Graptolites from Mandurama; by T. S. HALL, M.A., Biological School, Melbourne University.

[Plate VI.]

I HAVE to thank Mr. E. F. Pittman, A.R.S.M., Government Geologist, for kindly giving me the opportunity of examining a collection of graptolites from Mandurama. Mr. Pittman says: "They come from Mandurama, associated with rocks containing radiolaria, and in the same beds I found some specimens of trilobites—apparently a new species of *Agnostus*." The number of specimens is small, though several species are represented. Two only seem well enough preserved for recognition, and they appear to be new, though closely allied to well known forms. The new species are *Climacograptus affinis* and *Diplograptus manduramæ*, while an undesignated *Diplograptus* is also figured. There appear to be other species both of *Climacograptus* and of *Diplograptus* present, but the specimens are very indistinct.

CLIMACOGRAPTUS AFFINIS, *n. sp.*

(Pl. VI, Fig. 1.)

Hydrosome parallel sided, attaining its full width about three millimetres from the sicula, rounding rather rapidly to a point at the sicular end. Thecæ twelve inches ten millimetres, opening at right angles to the long axis of the polypary. In compressed specimens the mouth indents the edge of the polypary for a little more than a third of its width. Inner edge of thecæ not visible. Virgula free for about five millimetres. Virgella traceable for about three millimetres. No trace of lateral spines on the earlier thecæ.

The species is closely allied to *C. normalis*, Lapw., the only noticeable difference being the length of the virgella, a comparison having been made with specimens from Hartfell which were identified by the late Professor H. A. Nicholson.

DIPLOGRAPTUS MANDURAMÆ, *n. sp.*

(Pl. VI, Fig. 2.)

Hydrosome slightly tapering, two millimetres broad; length of figured specimen, nine millimetres. Thecæ fifteen inches ten millimetres; straight, parallel sided, inclined at about 20°. Aperture at right angles to the axis, overlapping about one half their length. The specimens are compressed.

The species is most closely allied to *D. bellulus*, Tqt.—so much so that I feel some diffidence in separating them; in fact the only difference seems to be the direction of the thecal apertures, which in *D. bellulus* are perpendicular to the

thecal length and not to the axis of the polypary—a difference which may possibly be due to the method of preservation. Perner* says that compressed individuals of *D. sinuatus*, Nich., are distinguished with difficulty from *D. modestus*, Lapw., and from *D. bellulus*, Tqt. A new specific name proposed with this proviso will do less harm than a doubtful record of a European species, with its attendant dangers of hasty correlation.

DIPLOGRAPTUS, *sp.*

(Pl. VI, Fig. 3.)

An imperfect specimen, with a projecting virgella and two lateral spines, is shown in Fig. 3. I have indicated a virgula, but its presence is only doubtfully indicated in the specimen. It does not belong to Lapworth's genus, *Cryptograptus*.

The present collection does not throw full light on the age of the beds. *Climacograptus affinis* belongs to a group ranging from Upper Ordovician into Lower Silurian (in the Lapworthian sense). The members of the group are difficult to distinguish, though what I regard as the closest ally of our species, namely, *C. normalis*, is Silurian. *Diplograptus manduramæ*, however, seems a little more satisfactory, as its allies, *D. bellulus*, *D. sinuatus*, and *D. modestus*, are all Silurian in Europe. There is, however, no trace on the one hand of the Ordovician *Dicranograptidæ*, nor on the other of the Silurian *Monograptidæ*; so that though the balance of evidence might seem to swing towards Silurian, still the evidence of these graptolites is so slight that a definite opinion cannot be pronounced on the strength of the material submitted.

The conclusion of course neglects the record of *Agnostus* and deals with the subject from the point of the graptolites alone.

IV.—Notes upon the occurrence of Gold in volcanic glass at Grassy Gully, Yalwal District, New South Wales; by J. B. JAQUET, A.R.S.M., F.G.S., Geological Surveyor.

[Plate VII.]

SMALL quantities of alluvial gold have been obtained in the creeks at Grassy Gully for a long time past, and about six years ago the precious metal was discovered *in situ* upon C. Moffatt's Scrub Lease, Parish of Buangla. More recently, considerable attention has been directed to the field on account of some

* Études sur les Graptolites de Bohême, 1897, Pt. 3, section *o*, p. 5.

rich patches of ore having been won. One small parcel, I am informed, yielded, upon being smelted at Dapto, gold at the rate of twenty-two ounces per ton. The great bulk of the ore, however, would seem to be of a low grade character, and to contain about five pennyweights of gold per ton.

Gold has been traced at the surface for a distance of about seven hundred feet in a north and south direction. In the Grassy Gully Mine a shaft has been sunk to a depth of ninety-eight feet, and short levels have been driven. The "lode," as seen in the levels, is about two feet wide.

The country rock consists of a devitrified, acid, volcanic glass, which is overlain by sandstones belonging to the Upper Marine Series of the Permo-Carboniferous Period. It exhibits various tints of colour—pale yellow, greenish yellow, and less frequently pink. Some specimens have a mottled appearance, and others the banded structure characteristic of rhyolites. Angular fragments of rhyolite, felsite, and other particles of volcanic material which have been caught up by the rock when in a plastic condition, can be distinguished by the naked eye.

Under the microscope some specimens exhibited a very perfect perlitic structure—All the specimens examined were devitrified.

The ore is chiefly composed of chalcedonic quartz; nevertheless the lode in no way resembles a quartz-reef. In the field, no wall or sharp line of demarcation can be distinguished between the ore and the country rock; and under the microscope the former only seems to differ from the latter in being highly silicified and crushed. Some specimens of the ore are only slightly shattered, while others have been transformed into a breccia, and we find specimens exhibiting various stages in silicification.

The gold occurs in an extremely fine state of division, associated in places with a little iron pyrites. In the rich ore it can be seen coating the joints and other planes of parting. Attempts which have been made to treat the ore in an ordinary stamper battery have resulted in failure, and the rich ore is now bagged and sent to the smelting works for treatment.

All the evidence seems to me to suggest that the rocks which form the subject of this paper represent ancient volcanic lavas. Insofar as they are overlain in places by Upper Marine beds, they must be of Permo-Carboniferous age, or still older. Having regard to their acid character, it is unlikely that they would retain their viscous condition long after being erupted, and it may be that they were heaped up about the vent from which they issued. The lava must have cooled

quickly, and consolidated as a more or less perfect glass; but during the long period that has elapsed since its consolidation, the glass has been almost completely devitrified.

Owing to earth movements the devitrified rock was shattered and crushed. The shattering, however, seems to have been confined to certain zones. Along these zones, where one would expect the country to be more permeable, siliceous, gold-bearing waters have found an entrance. These liquids have attached the shattered fragments of lava, and in many instances replaced them, molecule by molecule, with the material which they brought from below.

My colleague, Mr. G. W. Card, Curator and Mineralogist, after making an exhaustive microscopic examination of the Kalgoorlie ore-deposits, has come to the conclusion that they represent zones of country rock which have been crushed and otherwise altered.* It was while reading this paper that the idea of suggesting a somewhat similar origin for the auriferous rock at Grassy Gully first occurred to me.

At Yalwal Gold-field, which is distant but five miles from Grassy Gully, the ore-deposits consist of irregular-shaped masses of auriferous slate. These ore-bodies contain *en masse* a few pennyweights of gold per ton, and include small bonanzas of great richness. The auriferous slates are more or less silicified. This alteration, however, is not confined to the ore-bodies, and there are extensive bands of slate almost entirely replaced by silica yet devoid of gold. Some of the Yalwal ore, particularly that which was obtained a few years ago from a rich shoot in the Caledonian Mine, has a most remarkable resemblance to the ore which is now being mined at Grassy Gully. This fact, the proximity of the two deposits, and other features of similarity, seem to suggest that they have had a common origin; yet the country rocks which include the deposits are altogether dissimilar—one is volcanic glass and the other slate. So it would appear that we have evidence against the ore-deposits at these two localities having derived their gold by a process of segregation from the country rock. The precious metal has probably been brought in solution from a deep-seated source.

I have to thank Mr. G. W. Card for the series of excellent micro-photographs which illustrate this paper.

* Notes on the Country Rock of the Kalgoorlie Gold-field, Western Australia. Records Geol. Survey N. S. Wales, 1898, vi, p. 41.

V.—Contributions to our knowledge of Broken Hill; by R. BECK, Professor at the School of Mines, Freiberg.

[Translated from the Zeitschrift für praktische Geologie, March, 1899, pp. 65–71, by kind permission of the Author.)

[Plate VIII.]

SINCE the important work of E. F. Pittman and J. B. Jaquet* on Broken Hill has become more widely known, through a detailed critical review by Krusch in our Journal, the interest taken in this subject by our readers and fellow-workers has been repeatedly manifested.† The subject does not seem to us to have been by any means exhaustively treated, and the Author may therefore be able to direct attention to a few facts of great importance in rightly comprehending the genesis of this deposit, which have either not yet been mentioned in the discussion, or have not, at least, been sufficiently brought into prominence. For the purposes of his investigation there were at the Author's disposal very numerous and varied specimens which had been kindly donated to the geological collections of the Freiburg School of Mines by Mr. Schlapp, Mining Engineer, and, at a later date, by Mr. Gmehling, Metallurgist, and more especially by the New South Wales Department of Mines. There were, further, frequent opportunities of looking over large quantities of Broken Hill ores at the Freiburg Smelting Works, which had been consigned there, and, by permission from the Director of the Imperial Smelting Works, of picking out what was of scientific value. To all these donors it is desired to hereby duly convey our thanks.

The acquisitions of earlier date had already been scientifically examined by A. W. Stelzner. Inspection, however, of manuscripts connected therewith, which were probably left by him, or of the literary matter generally left by the deceased, was not open to us in the prosecution of our studies.

Our observations are naturally limited to the mineralogical-petrographical constitution of ore and country-rock, and especially to the structural relations so important genetically; while, as regards the general geological relationships, we can trust implicitly to the work of Jaquet,‡ which bears evidence of the greatest reliability.

---

* Zeits. prakt. Geol., 1897, p. 94.

† Zeits. prakt. Geol., 1897, p. 314; 1898, p, 392; 1899, p. 49. Also compare G. Erafelder "The Silver, Lead, and Zinc Mines of Broken Hill, N. S. Wales," Mining and Metallurgical Journal, 1896, Nos. 48, 49, 51. See also Zeits. prakt. Geol., 1893, p. 295; 1894, pp. 402 and 431; 1895, p. 6; 1897, p. 94; 1898, pp. 290, 306, 309, 310.

‡ J. B. Jaquet, Geology of the Broken Hill Lode and Barrier Ranges Mineral Field. Sydney 1894 (Mem. Geological Survey, N. S. Wales—Geology 5).

As a minute microscopical examination of the country rock, with the exception of the short description of the garnet-quartzites by Jaquet (p. 46, Plate I, Figs. 1 and 2), is so far wanting, we shall preface our remarks with this.

The predominating rock on the hanging-wall of the great ore-body is a medium-grained garnet-gneiss which, in consequence of a banded arrangement of garnet and felspar, appears striped on a cross-fracture. This rock consists principally of a peculiar verdigris-coloured orthoclase, a little plagioclase, scanty grey quartz, yellowish red garnet, and dark mica. The verdigris-coloured orthoclase is of quite the same nature as that in the cordierite-gneiss of Bodenmais and in the pegmatites of Anneberg. It contains tiny inclusions of a light-brown liquid, aggregated into clouds and streaks, often with movable gas bubbles. No character could be found to identify it with microcline. The green colour disappears at a red heat. It may also be mentioned, as seems to be as yet but little known, that the verdigris-coloured orthoclase of Anneberg assumes its characteristic colouring only on exposure to the open air. Nothing is known to us of the observation of such pecularities at Broken Hill. The attention of investigators on the spot is now called to this circumstance. By chemical examination of perfectly clean flakes of this Broken Hill felspar, Kolbeck failed to discover metallic compounds which might be regarded as pigments.

The felspar and quartz form irregular grains with many indentations. Both frequently enclose sharply defined little garnet crystals and small scales of the brown micas, which must, therefore, be regarded as the earliest constituents in the course of crystallisation. Many of the orthoclase grains are even thickly studded with garnet crystals. Extremely fine scaly threads of sericite twist through the rock and have even invaded the orthoclase along tiny cracks. This must be regarded as a secondary structure, due to the agency of pressure, which also manifests itself in the undulose extinction of the orthoclase. Very frequently tiny grains and crystals are scattered through the rock of a mineral—iron-grey by reflected light, only very faintly grey by transmitted light, and difficult to dissolve in acids, even in fluoric—which occurs as inclusions in the garnet and is therefore a primary constituent separated at an early stage. Judging by its chemical and optical properties this mineral is titaniferous iron ore, such as has already been repeatedly described in garnet-gneiss. Moreover, by washing the powder even of what appears to be perfectly normal rock of this kind, a little galena and blende are not unfrequently obtained. These seem to be of secondary introduction; at least it was impossible to obtain proof of their having been originally present in the country rock. Finally the presence of small zircon and rutile crystals must be mentioned. With a magnet, small quantities of magnetite, scarcely worth mentioning, may be extracted from the powder. Deviations from this rock-type sometimes result from the almost entire disappearance of the garnet, as well as, very frequently, from a very strong development of sericite. Many specimen proved to be sericitized through and through.

The garnet-gneiss often contains bands of garnet-quartzite, which is composed of dusky quartz and garnet drawn out into streaks, together with some biotite. A true hornstone structure, pointing with certainty to contact metamorphism on the flanks of the granitic rock of the Barrier Range, is not shown by this variety of rock. The quartz individuals, on the contrary, as is the case in most gneisses, are mutually interlocked by toothed peripheries. The garnet often forms very irregularly ramified individuals, and is, save a few quartz-grains, mica-scales, and opaque substances not determinable with certainty, ordinarily free from inclusions. Tiny zircons are scattered through the rock; here and there also are very small pyrite crystals and, pretty frequently, those titaniferous iron granules already mentioned in connection with the garnet gneiss. Sericite frequently occurs in the garnet-quartzite, and bands rich in sericite may result.

Let us now pass to the ore itself; putting aside, however, all the secondary formations of the upper levels, and confining ourselves entirely to the sulphide ore-bodies. These consist principally of an intimate mixture of argentiferous galena and blende with a peculiar grey-blue quartz, with garnet and rhodonite, as well as with fluor. Of these the fluor is generally inconspicuous and escapes the naked eye; only exceptionally does it occur in visible grains, colourless or whitish for the most part, or, still more rarely, in vein-like aggregates up to three centimetres* in length. Less frequent is the additional occurrence of copper-pyrites, iron-pyrites, mispickel, and calcite. Orthoclase, the occurrence of which in the ore Jaquet lays stress upon, we have not hitherto met with in the ore-body proper. We have also not observed anything of the magnetite which, according to Bergeat, was discovered by Stelzner in the Broken Hill ore, and which he is said to have emphasized. We certainly did find a small piece of ore marked by Stelzner, "Traces of magnetite"; but a special examination of the specimen gave no support to this supposition.

Of the greatest importance genetically must be the relations of mutual intergrowth of the constituents enumerated. Let us, in the first instance, consider the relation between ore and garnet. The presence of this silicate is by no means rare. One of the larger pieces of ore can scarcely be picked in which it cannot at least be detected. Its ocurrence is twofold. At one time the garnet, or its aggregates, forms angular fragments which are surrounded by ore on all sides. This, in the first place, can occur under microscopical conditions. Next, it is a question of plain micro-breccias, such as appear in Fig. 7, which, like the other illustrations, has been drawn as true as possible to nature and by means of a partial copying of photo-micrographs. According to these, pieces of a crushed garnetiferous rock, containing but little quartz, have been cemented by galena and blende. In addition to liquid inclusions the garnet also contains a few tolerably large ones of

* [1·18 inches.]

blende and galena. It is, however, possible that these apparently wholly isolated ore-particles are only transverse sections of tongues extending into the interior of the grains of garnet. A second occurrence of garnet is as idiomorphic, decidedly freshly separated crystals in the midst of the ore mixture. These garnets are generally very rich in genuine ore-inclusions. This is, indeed, often capable of proof in large specimens. We possess, for instance, from the Proprietary Mine, Block 10, a half-crystal of the combination $\infty 0$, 202, measuring up to 2·5 centimetres,* situated in the midst of the ore. It shows no trace of corrosion; the faces smooth as glass, indicating rather a recent separation: still more so the interior, for this is filled with a mixture of galena and small garnets. Occasionally the filling of such a shell converted into garnet has been leached out at a later date. Before us, from the same mine, in the midst of a very cavernous piece of ore, lies a whole druse of such a hollow formation of garnet—which, deviating from the rule prevailing there, is not brown-red but yellowish-brown in colour—from which rhodonite might have been leached. The crystals of the newly-formed garnet, generally $\infty 0$, are especially sharp when situated in the midst of the blue quartz which is so characteristic of this ore. This quartz occurs partly in isolated angular splinters in the midst of the cementing galena and blende, partly in larger compact portions which may then be interspersed with garnets down to very tiny scarcely perceptible crystals. Of this twofold occurrence of garnet just described—an older generation, most likely taken over from the country rock, and a younger one—the specimen portrayed in Fig. 2, is an instructive example. In the midst of a mass consisting essentially of blue quartz with idiomorphic yellowish-red garnets and some galena, lies a blunt-edged fragment of light yellowish-red very fine-grained garnet-rock, which is surrounded by a wreath of somewhat dark-coloured, newly-formed garnets, and has been penetrated by very delicate little veins of galena. Other fragments of garnet-rock in the ore we see surrounded by blue quartz quite as usual, in such a way that the longitudinal individuals are placed approximately at right-angles to the contour of the inclusions. Such angular inclusions of fine-grained garnet-rock, or garnet-quartzite, do not appear to be rare in the sulphide ore-body. We collected several of these from the ore-heaps of our smelting works. We also possess a lump of ore which contains a fragment of this kind six centimetres† broad. Galena has almost always been deposited in cracks in these inclusions.

It may be here mentioned that inclusions of garnet-gneiss also occur. For instance, we have a small piece of this description which has a shell of fine-grained garnet-quartz aggregate, and is veined throughout with galena and other ores. The considerable percentage of silver contained in this specimen, which is nevertheless poor in ore, viz., 0·015 per cent,‡ according to an assay kindly made by

*[·98 inch.]
† [2·36 inches.]
‡ [Equals 490 oz. to the ton of ore.]

Herr Kolbeck, appears to indicate the presence of valuable silver-ores in these miniature veins. Especially interesting in this specimen is the casing mentioned. In this there are to be observed delicate layers of sulphides, particularly galena, closely investing the inclusions—an indication of concentric deposition of ore.

Let us now pass to the rhodonite. This is not so generally distributed as the garnet. Where met with it forms, in the midst of the sulphide ore, either larger crystalline aggregates, always intergrown with granules of garnet, or isolated fragments which were doubtless highly corroded before being imbedded in the ore-mixture. This process of corrosion, in its gradual development, can be clearly traced in various specimens. Some of the garnet-rhodonite aggregates are almost entirely free from ore. At the most, they are interwoven with delicate veins of galena and blende which here and there send out tiny feelers between the cleavage cracks of the rhodonite—which is otherwise free from ore-inclusions—and into the spaces between detached granules contiguous to those veins. This interweaving with tiny feelers increases more and more. Finally, the whole fabric of the crystalline aggregate becomes disintegrated. Fig. 9 gives a clear representation, true to nature, of this last state. The individual rhodonite grains, closely bound with such ore and with garnet, have, corroded by mineral solutions, acquired a skeleton-like development they by no means had before. The loss of material is evident not only in the perpiheral portions with their wonderful indentations, but the corrosion of cross fissures and cleavage cracks has also spread deep into the interior; so that what appear to be completely isolated inclusions of sulphide of zinc are to be seen in large numbers in the midst of the corroded rhodonite. In the slide figured garnet is still to be found with the rhodonite, a vestige of the original crystalline garnet-rhodonite rock; and besides, as a new formation, colourless fluor—rarely violet-blue. As regards the succession of ores in this compound, they appear to have been deposited about the same time. Wherever the ore has filled the interstices between fragments of garnet and rhodonite a kind of microscopical crust-structure is at times established, as may be seen in Fig. 9. At one time galena, at another blende, forms the outer layer of these micro-veins. Much the same may be said of the copper pyrites, where it appears in small quantities in the ore-complex. Larger developments of copper pyrites are mostly associated with blue quartz. The structural conditions prevailing then are shown in Fig. 10. The main portion of the ore consists here of bluish quartz. The individual grains, with somewhat serpentine outlines, exhibit a remarkable appearance as seen under crossed Nicols. Parallel lines of liquid inclusions, to some extent plainly light-brown in colour and with movable bubbles, traverse entire aggregates of granules, regardless of the boundaries of individual quartz grains. This appears to indicate that the solutions from which this quartz separated were in motion during crystallization. Tiny angular crystals of garnet and a few minute prisms of apatite are seated between the quartzes. Some of the

garnets are surrounded by small flakes of chlorite in radial groups. Finally, the ore—copper pyrites and blende associated with some fluor and calcite—occurs partly in granules scattered between the quartz individuals and partly in larger masses which here and there interrupt the course of the liquid inclusions in the quartz. A linear arrangement of garnet crystals occasionally to be observed along the mass of copper pyrites may be explained in two ways: either these bands of garnet have not been deposited until after the pyrites, or the latter has replaced a now vanished constituent formerly flanked with garnets in this way. It is to be observed that the isolated copper pyrites interspersed among the quartz is occasionally developed into short little crystals.

After a little practice it is easy to distinguish with reflected light the various kinds of ore in the sections. It might be stated here that the galena, where it forms apparently homogeneous grains, still seems to contain extremely delicate lamellar interpositions of another darker ore, which of course can scarcely be seen on account of their minuteness and cannot be determined more closely. Perhaps they are combinations of silver and sulphur determining the proportion of silver contained in the galena.

The larger masses of blue quartz were also subjected to microscopical investigation. They often show a typical mortar-structure—*i.e.*, large quartz grains are often bordered or crossed vein-wise by zones of a complete quartz mosaic of small angular fragments. The garnets interspersed with the blue quartz are also frequently shattered, and galena has found its way into the small cracks so formed. Quartz aggregates have been crushed and repaired again. In the midst of the ore there occur coarser quartz breccias, the fractures of which are only imperfectly repaired, and the cement consists here of quartz and secondary galena. All these structures testify to pressure effects and separation processes several times repeated.

To the description of the structural condition of the true Broken Hill ore-complex I might yet add the observation that Jaquet (*op. cit.* Pl. VI, Fig. 2) figures an orthoclase, in part metasomatically replaced by galena, which entirely resembles our corroded rhodonite. It may not be quite out of the question that there is a confusion with rhodonite here.*

Let us now examine the structural relations at the junction of the ore-body with the garnet-gneiss. We were able to observe these on a large lump which very likely came from the hanging wall. Fig. 11 gives a representation of these as faithfully as possible. The right half consists of normal fresh country rock. The frequently branching black streaks in the illustration represent the mica flakes. Between the garnet-gneiss and the ore-body is interposed a distinctly banded zone, 1·2 centimetres wide,† to which the individual marginal layers of the ore-body

* After reading the paper of Prof. Beck, I have made a careful re-examination of the microscopic slide from which Fig. 2, Pt. VI is reproduced. Prof. Beck is undoubtedly correct: the mineral which is undergoing replacement is rhodonite, not orthoclase.—J. B. JAQUET.

† [Equals two-fifths to four-fifths of an inch.]

are parallel but intersect the foliation of the gneiss. Then follows a band rich in garnet with irregular patches of ore consisting principally of galena; after that a zone with much blue quartz and little garnet and ore. In this the quartz grains that are the most stretched lie at right angles to the margin of the ore. In the ore-body itself now following, consisting principally of galena, lie angular splinters of blue quartz, while garnet grains are also interspersed here and there. Our specimens did not permit of an investigation of the conditions prevailing on the footwall border. Through Herr Gmehling we received, however, from the footwall of the lode (from the so called "intrusion" of the Proprietary Mine), highly glistening pieces of quartz of a decided greyish-blue colour with a moirée-like fracture, which permit of the observation of very remarkable phenomena. These pieces are composed of large individuals with irregularly wavy borders; often with indications of mortar structure. In the midst of the individual grains, besides small colourless needles of an undetermined mineral, there are to be seen numerous tiny scales of biotite, sharply defined little crystals of garnet and also galena wholly enveloped by quartz. Galena is also deposited in the cracks which pervade the quartz grains.

Let us now endeavour, lastly, to supplement the evidence obtained by Jaquet's statements; and in conclusion draw deductions from the whole as to the genesis of the Broken Hill ores. The Broken Hill lodes, as we have seen, decidedly do not represent a syngenetic bed constituting a subordinate member of the country rock series, somewhat like many iron-ore deposits of the crystalline schists. The ores composing them except the gangue, and in part the gangue itself are, as we now see them, of later formation than the country rock. The gangue is in part clearly fragmental; such as a portion of the garnet, the quartz, and also of the rhodonite—products of the operation of tremendous pressure. After these mechanical processes they were first enveloped by the sulphide ore, which at the same time took up newly-separated garnets. Many of these inclusions resemble fragments of the country rock, as they occur in fissures imbedded in the midst of the ore. Whether this also applies to the rhodonite, or whether that represents an earlier deposition within the cavities formed, is doubtful. I would direct attention to the occurrence at Kapnik. The garnet-rhodonite aggregates, as yet but little mineralized, give rather the impression of a rock of co-formation with the gneiss. Evidence of the existence of such a rhodonite rock in the Broken Hill gneiss outside the ore-body would therefore be of importance.

Part of the enclosed gangue material, the rhodonite in particular for certain, in addition to shattering by mechanical agencies, has undergone definite corrosion before being imbedded in the ore; consequently the deposition of ore was simultaneously associated with metasomatic action. It may have been that, at an earlier stage, minerals now practically non-existent—for instance calcite—were mineralized in the same way.

Broken Hill has only non-essential characters in common with the Schwarzenberg type, since magnetite is wanting, and above all since a sahlite-skarn, as a real basis of the deposit, is absent. In many other more subordinate points does that type also differ, as will be fully demonstrated by the Author elsewhere.

Against a bedded theory, as regards Broken Hill in general, we have the absence of all schistosity; of all division into beds differing from one another in composition, parallel with the foliation of the country-rock. It is certainly conceivable that we are dealing with a metasomatic deposit; in other words, that a bed of garnet-rhodonite rock has been entirely mineralised by degrees. We must not, however, attach too much importance to these metasomatic changes. The structures described by us lead rather to the same theory as that which Pittman and Jaquet have already advanced based upon their survey of the whole. According to that the ore-body at Broken Hill is primarily the result of an enormous folding over of strata from the bending zone of a saddle in the gneiss. The bursting open of a cavity with uneven walls in the folding mass must certainly have led to the detachment of whole flakes of country-rock, and since shearing between the foot- and the hanging-wall must have taken place in at least a minor degree, a further shattering of these flakes would occur. The spaces partly occupied by rock *débris* could then have been filled with ore and the accompanying gangue such as fluor and newly-formed garnet. The possibility of the formation of such saddle reefs has already been sufficiently demonstrated by the example of Bendigo, which is confirmed from many quarters and has been thoroughly investigated.* Some doubt may certainly arise from the colossal scale of the Broken Hill occurrences. It can only with difficulty be conceived that such an upheaval of folded strata could have taken place over so great a distance as two kilometres.† We have, however, in the region of tectonic geology, kindred phenomena on a much more stupenduous scale, which are well vouched for. I would only recall the gigantic sheet of olivine-diabase, the Great Whin Sill of the English Carboniferous Formation which, according to Geikie,‡ can be traced for one hundred and twenty-nine kilometres.§ Here, also, the uplift must surely have preceded the filling-up; the intrusion of the irruptive rock was not the real cause of the creation on so large a scale of a cavity parallel with the stratification. Jaquet, moreover, is very well acquainted with the fragments of country-rock in the ore-body described by us. He further adds that the periphery of the ore does at times intrude into the country-rock, and may here and there pass across the bedding planes; in his opinion this is connected with the replacement of the country-rock by ore (*op. cit.*, 63). According to him, the western border is the most irregular. Here the ore forms bulges which here and there cross the

* Compare, among others, Rickard "The Bendigo Gold-field." Trans. A.I.M.E., 1893.
† [One and a quarter miles.]
‡ Geikie, Ancient Volcanoes, I, p. 82.
§ [Eighty miles.]

bedding planes of the country-rock. On the other hand, it appears to Jaquet that the absence of any flucan course along the wall is against the occurrence of true shearing. But this may perhaps be explained thus: After a final dynamic movement the mass has long since come to rest, and the solutions, the powerful corroding properties of which we have seen indicated, have again obliterated the ancient slickensides. Were not all the inclusions we have described surrounded by purely chemically produced envelopes?—which again supports the theory that exclusively chemical agencies were at work long after the final mechanical operation.

We now come to speak once again of the garnet; the presence of which in the ore-body, in part as remnants of portions of the country-rock, but partly also newly crystallised and younger than a portion of the ore encompassed by it, we had demonstrated afresh. This occurrence of garnet constitutes the principal argument of all who take the Broken Hill deposits for true beds, as we did ourselves before examining the matter more closely. We think, however, that this one argument cannot shake the many others that speak for a vein-nature. We will even admit the occurrence of garnets in deposits of the nature of veins to be a rare exception; just as we have lately had to make further concessions in this respect to orthoclase.* In the Barrier Range, to which Broken Hill belongs, there are moreover other similar deposits containing garnet. Jaquet describes veins at the Pinnacles Mines, to the south-west of Broken Hill, the filling of which consists mainly of an intimate mixture of argentiferous galena and magnetic pyrites with garnet and quartz.

In a piece of ore from the Consols Mine lying before us, we observed under the microscope a granular crystalline aggregate of quartz-veins, between which lie irregular patches of galena, sulphide of zinc and iron pyrites. A few garnets are also interspersed among the quartz; but, besides these, galena and well-defined little crystals of garnet also occur as inclusions within the quartz, which latter has the structure of the Broken Hill quartz illustrated by us in Fig. 10. The material from the Pinnacles examined by us is too insignificant to admit of safe conclusions being arrived at. Perhaps in the future we may obtain a more complete collection of specimens from there.

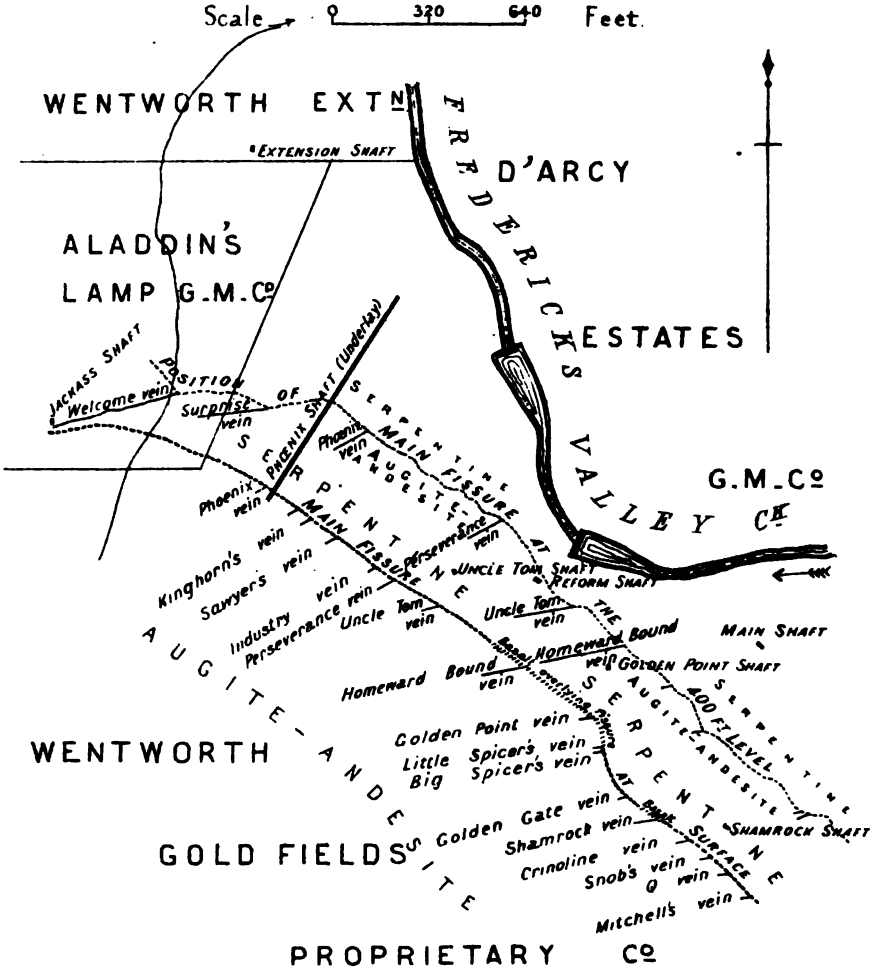
Before concluding, we would again summarise our opinions by declaring that, in the light of our present knowledge, Broken Hill is, as shown by Pittman and Jaquet, to be ranged rather with the vein occurrences than with true ore-beds. In any case it forms a quite peculiar type not yet recognised outside the Barrier Range—the Broken Hill type. It represents veins of a garnetiferous variety of the siliceous zinc-lead ore formations of the crystalline schists, in connection with metasomatic changes of portions of the country-rock.

* Compare Lindgren, Orthoklas als Gangmineral. Zeits. prakt. Geol., 1899, p. 49.

PLATE I.

Sketch Plan of part of the Lucknow Gold field.

Sketch Plan of part of the LUCKNOW GOLD FIELD



(Taken from Mining Managers' plan)

6121

Photo-lithographed by
W. A. Gullick, Government Printer,
Sydney, N.S.W.

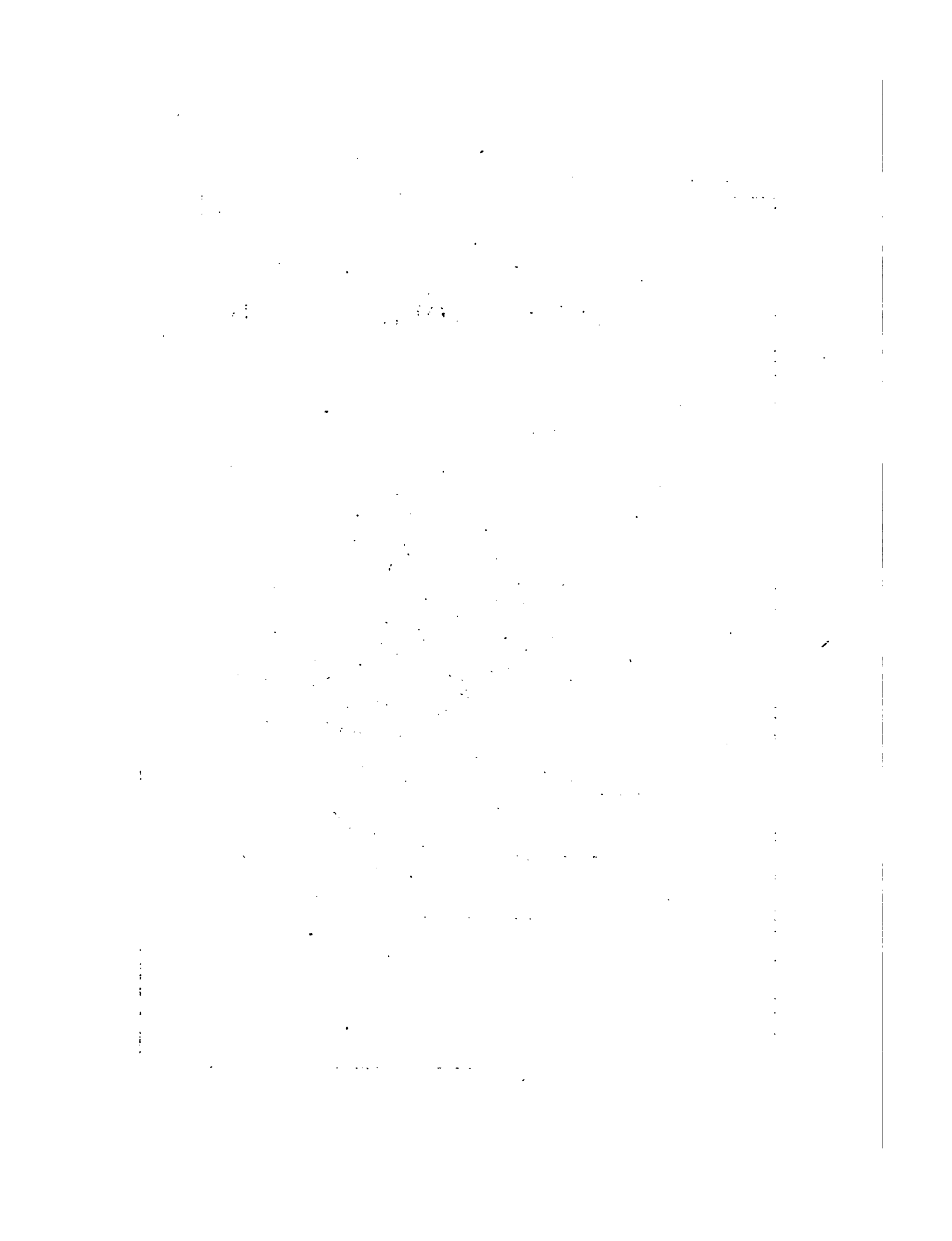


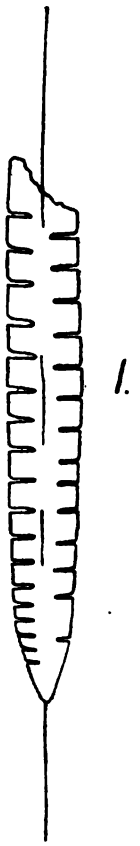
PLATE VI.

Fig. 1. *Climacograptus affinis*, T. S. Hall.

Fig. 2. *Diplograptus manduramæ*, T. S. Hall.

Fig. 3. Diplograptus, sp.

All figures x 5.



1.

2

3.

81121

Photo-lithographed by
W. A. Gullick, Government Printer,
Sydney, N.S.W.

PLATE VII.

Fig. 1. Shattered and silicified volcanic glass from the "lode," Grassy Gully Mine; magnified 12 diameters; ordinary light. A portion of the sample from which this section was cut yielded, upon being assayed by Mr. J. C. H. Mingaye, as under—

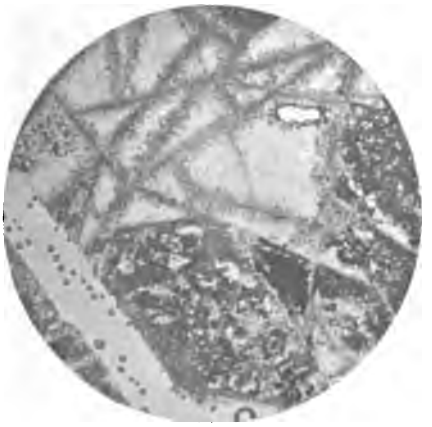
Gold ...	...	5 dwt.	10	grs.	per ton.
Silver...	...	3 „	6	„	„

Fig. 2. Brecciated and silicified volcanic glass from the lode, Grassy Gully Mine; magnified 12 diameters; ordinary light.

Fig. 3. Devitrified volcanic glass ("country rock"), from Grassy Gully Mine; magnified 12 diameters; ordinary light.

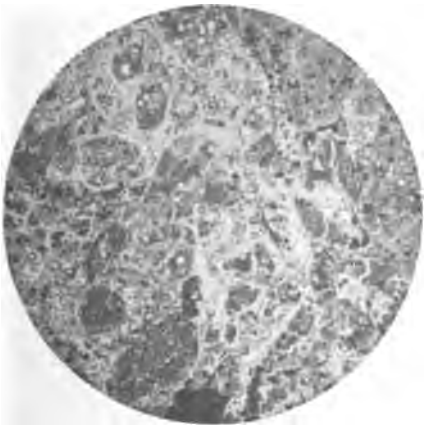
The glass has a perlitic structure.

Fig. 4. Devitrified volcanic glass ("country rock"), with a portion of an included fragment of Rhyolite, from Grassy Gully Mine; magnified 12 diameters; ordinary light.



1

2



3

4

PLATE VIII.

Fig. 1 [7]. Micro-breccia of garnet-rock; slightly enlarged. (*g*) garnet, (*q*) quartz, (*b*) galena, (*z*) blende.

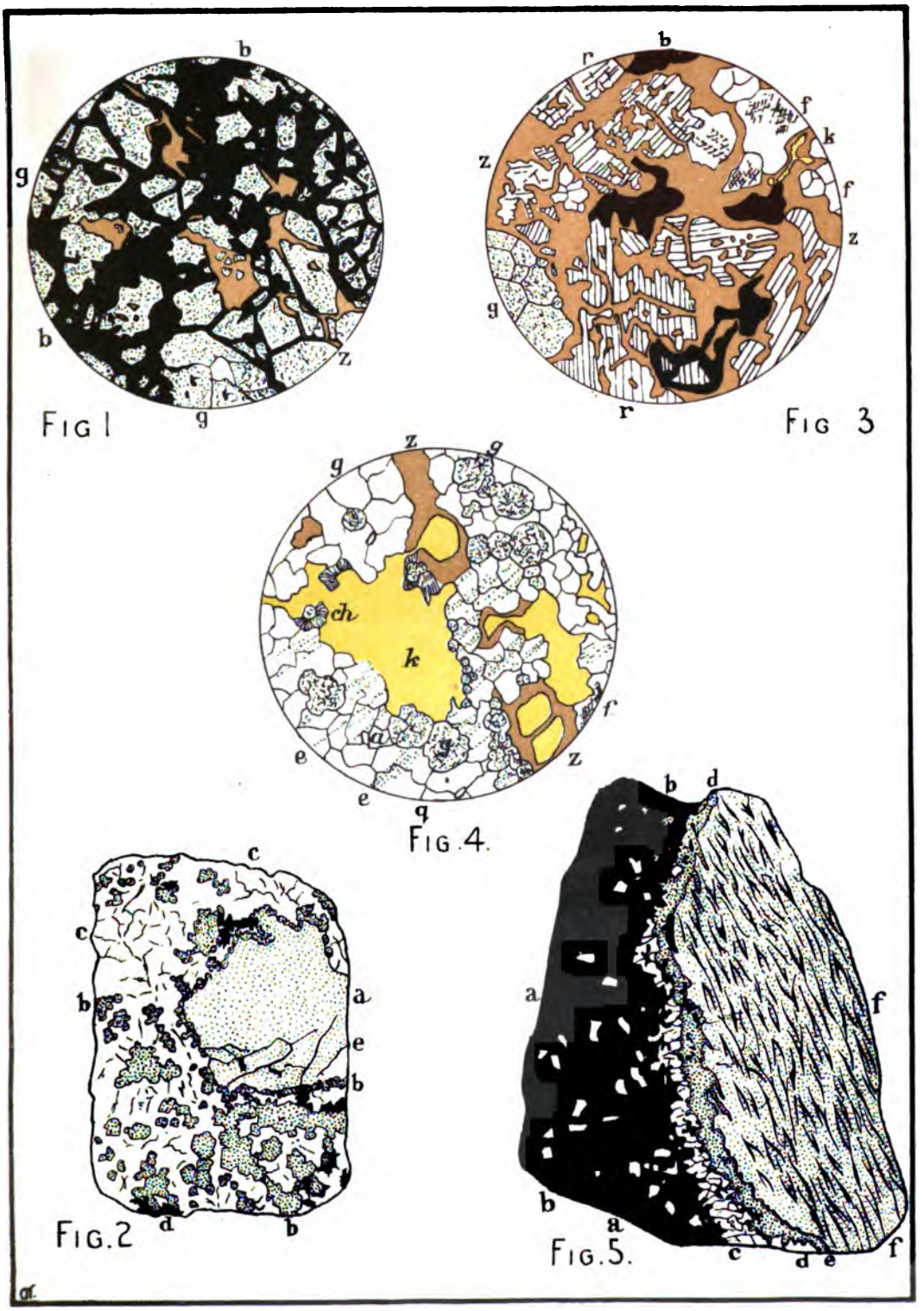
Fig. 2 [8]. Fragment of garnet-rock in the ore-body, fringed by newly-formed garnet; slightly diminished. (*a*) garnet-rock, (*b*) newly-formed garnet, (*c*) quartz, (*d*) galena, (*e*) threads of galena.

Fig. 3 [9]. Garnet-rhodonite aggregate with immigrant ores; slightly enlarged. (*g*) garnet, (*r*) rhodonite, (*f*) fluor, (*b*) galena, (*z*) blende, (*k*) copper-pyrites.

Fig. 4 [10]. Copper-pyrites in the blue quartz; slightly enlarged. (*q*) quartz, (*e*) inclusions, (*g*) garnet, (*ch*) chlorite, (*a*) apatite, (*f*) fluor, (*k*) copper-pyrites, (*z*) blende.

Fig. 5 [11]. Specimen from the hanging-wall of the ore-body. (*a*) galena and blende, (*b*) garnet (dotted), (*c*) quartz, (*d*) quartz with a little galena and garnet, (*e*) garnet with a little ore, (*f*) garnet gneiss with flakes of mica.

Note.—The figure numbers in square brackets are those quoted in Professor Beck's original paper.



61121

Photo-lithographed by
W. A. Gullick, Government Printer,
Sydney, N.S.W.

SEP 10 1902

DEPARTMENT OF MINES AND AGRICULTURE, SYDNEY.

RECORDS

OF THE

GEOLOGICAL SURVEY OF NEW SOUTH WALES.

Vol. VII.] MARCH, 1902. [Part 2.

VI.—An Eclogite-bearing Breccia from the Bingera Diamond Field: by GEORGE W. CARD, A.R.S.M., F.G.S., Curator and Mineralogist.

[Plates IX, X, XI.]

THE breccia that forms the subject of this note occurs at Ruby Hill, about twelve miles south of Bingera, on the Barraba road. The Bingera Field, and the adjacent vicinity of Inverell, have been producing large numbers of diamonds from alluvial deposits for some years, and are still doing so. The mining operations that have been carried on at Ruby Hill, together with the evidence for the occurrence of diamonds, have been recently described* by Mr. E. F. Pittman, A.R.S.M., Government Geologist. The breccia occupies† a pipe, piercing sedimentary rocks of Carboniferous age, traversed by several dykes of basalt, and cut off on one side by intrusive quartz-felsite. A plan of the pipe is given by Mr. Pittman, who describes the breccia as follows‡:—"It (*i.e.*, the breccia) has been decomposed to a depth of only a few feet, and in its undecomposed state it is of a dark-greenish blue colour. It is made up chiefly of angular fragments and masses (though there are also occasional rounded pebbles) of other rocks, such as claystone, amygdaloidal basalt, quartz-felsite, eclogite, &c., with garnets, chrome-diopside, magnetite, zircons, and a considerable quantity of secondary calcite. The rock fragments making up the breccia have in many cases an altered or bleached

* The Mineral Resources of New South Wales, 1901, pp. 392-395. Photograph and plan.

† *Idem.* p. 393.

‡ *Idem.* p. 393.

appearance, such as would be produced by heat, but their edges do not appear to have been fused." To this description there is nothing to add, but analysis has since shown that the diopside is a vanadium variety and does not contain chromium (see page 35).

The material available for the present examination were as follows:—

1. Basalt.
2. Masses of breccia.
3. Drift sand.
4. Sand from sluicing operations.
5. Masses of eclogite.

(1) BASALT.*—As already mentioned, this occurs as dykes cutting across the breccia-pipe. Weathered specimens sometimes exhibit a banded structure, the lines of flow being often diverted by inclusions of foreign particles. Amygdales of calcite and zeolites are abundant, and calcite encrusts joint-faces. Unweathered, it appears as a dense black rock, having a lumpy fracture, and showing as inclusions abundant grains of pink garnet and green pyroxene, together with rounded lumps of rock and a little felspar. The so-called kelyphite-rim is sometimes very apparent round many of the garnet inclusions. Among the rock-fragments eclogite greatly predominates; it is readily recognised by means of its constituent garnet and pyroxene. Under the microscope it is seen to be a fine-grained, fluidal, olivine-basalt, consisting of small phenocrysts of augite and olivine, set in a base crowded with fluidally-arranged felspar-crystallites and brownish glass specked with magnetite-due dust. Colour-banding, due to the linear distribution of magnetite, sometimes occurs, taking the form of narrow wavy dark bands between lighter, broader ones. Very numerous inclusions are present.

Olivine.—Small phenocrysts, occasionally idiomorphic; incipient serpentinization.

Pyroxene.—Small, idiomorphic augite; pale brown in colour, deepening marginally. The phenocrysts are not numerous.

Felspar.—The small crystallites of the base generally show twin-lamellation; extinction-angle rather low.

The Inclusions:—

Eclogite.—Abundant, in pieces of all sizes. Disintegration can be traced down to particles consisting of two constituents only (Pl. XI, Fig. 2), and finally to the isolated minerals garnet, pyroxene, felspar, and spinelle. The eclogite itself will be described below, but the alteration undergone by its liberated constituents under the influence of the molten magma is of considerable interest, and may now be referred to.

* Specimens of this basalt, containing embedded garnets, were shown me several years ago by my colleague, Mr. J. E. Carne, the garnets having been locally mistaken for rubies. This fact is alluded to at some length by Mr. J. M. Curran (Proc. R. Soc. N. S. Wales, 1896, p. 248).

As regards garnet,* the successive changes undergone are portrayed by the photo-micrographs on Pl. XI. The plumose or fern-like aggregates of magnetite (?) dust, which appear to represent the last stages of the alteration—as the whole mass is sometimes replaced by it—are very peculiar. This is well shown in Fig 4, while in Fig. 2, such a zone is seen not only enveloping garnet, but also extending up one side of the still-attached pyroxene: probably it appertains to garnet now completely destroyed. The typical "kelyphite-rim," consisting of an outer zone of brown (opaque white by reflected light) radially fibrous, doubly-refracting material, is seen on Fig. 1. The alteration of the pyroxene also appears to be well worthy of attention, but has not been further studied in connection with this investigation. Spinelle occurs in yellowish-brown fragments, with a broad black margin. It appears to be pleonaste, and while it may have been derived in part from the disintegration of eclogite, has most probably come principally from the rock-inclusion next to be described.

Augite-Pikrite.—Specimen 4519/3 shows a small portion of an inclusion quite different from the eclogite. It is holocrystalline, medium-grained, of granitic structure, and consists of olivine, pyroxene, amphibole, and pleonaste.

Olivine.—Partially serpentinised.

Diopside.—Very pale green; monoclinic; encloses pleonaste; extinction-angle of at least 40°.

Amphibole.—Axis colours, greenish-yellow to colourless; cleavage characteristic: encloses pleonaste.

Pleonaste.—Abundant; green; sometimes appears to enclose olivine.

Bronzite (?).—Slightly pleochroic.

(2) BRECCIA.—The hand-specimens available agree with the description given by Mr. Pittman.* They are dull bluish-green in colour, weathering ochreous, and in general appearance closely resemble the breccia from Kimberley, South Africa. Calcite is always present. Unweathered, the breccia is seen altering into a dull-green earthy chloritic-looking substance with a pale green streak. The component fragments are angular to sub-angular, of all sizes, and when recognisable comprise claystone, fluidal melaphyre, and masses of rounded eclogite. The melaphyre is most clearly seen in the ochreous lumps. These fragments are embedded in a granular matrix, which appears to consist largely of the minerals liberated on the disintegration of the eclogite. The lumps of eclogite can be seen altering externally into the earthy green substance just referred to, the garnets remaining untouched by the agencies of decomposition. The great

* *Op. cit.*, p. 393.

alteration, other than weathering, that the breccia has undergone renders microscopic examination very difficult. Among the mineral-fragments recognisable are pyroxene, garnet, felspar, bronzite (?), cyanite, quartz. Carbonaceous matter has also been found.

(3) and (4.) SAND from sluicing operations and from the drift.

The following minerals have been identified in the sand:—

Garnet—A pink variety (pyrope), sometimes with a white kelyphite-rim.

Pyroxene—Dull bottle, or blackish-green lumps, breaking with a conchoidal fracture; in great abundance.

Pyroxene—Emerald-green.

Felspar—Opaque-white; a little only.

Pleonaste—A little.

Quartz—Occasionally.

Zircon—Straw-coloured.

Cyanite ?—An occasional grain, of doubtful identity.

Rock-fragments are also present.

From what has been already said, it will be understood that this sand has been derived from the disintegration of a variety of rocks; a more detailed examination of it did not, therefore, seem necessary.

An analysis of the pink garnet is quoted by Curran* as follows:—

SiO_2	39·57
Al_2O_3	23·68
Fe_2O_3	·18
FeO	10·04
MnO	3·76
CaO	8·76
MgO	14·45
	100·44

This shows it to be an alumina-magnesia-iron-lime-silicate belonging to the pyrope group. While it is certain that the bulk of the green pyroxene is omphacite, the presence of amphibole in the pikrite (*see* p. 31) points to one source of confusion, and it is probable that more than one variety of pyroxene may be present. There can be no doubt, however, that the greater proportion of these pyroxene grains are identical with the omphacite of the eclogite (*see* p. 34.) In any case, no very useful purpose would be served at present by continuing the examination.

* *Op. cit.*, p. 249.

5. ECLOGITE.—From what has preceded, it will be gathered that specimens of the eclogite may be obtained from the intrusive basalt and from the breccia. It seems probable that the basalt derived its eclogite from the breccia through which it has broken. Most of the specimens available are more or less weathered. In commenting on the garnets found in the drift, Curran mentions* having found them *in situ* in "several pieces of a coarsely crystallised basic rock." This latter he describes as "a holo-crystalline granular basic rock, composed of pyroxene, felspar, and kelyphite rings of a composite substance surrounding garnet." There can be no doubt that this was the eclogite now under description. The present examination has been conducted in the main on a small, comparatively fresh piece.

Description.—Blackish when fresh, weathering brown; fractured and weathered surface lumpy; granular, the three principal constituents being pretty uniform in size. Specific gravity 2·9, rising in the more weathered specimens. Green pyroxene, pink or black garnet, and fresh felspar, in grains, averaging perhaps 2mm. in diameter, can be readily distinguished with the unaided eye.

Constitution.—Under the microscope the same three minerals, together with cyanite, are seen.

Garnet.—Very abundant. Every stage of alteration, from clear crystals with kelyphite rims to those blackened and altered right to the centre, may be seen. That this alteration is not due to weathering is apparent from the fact that in the soundest piece of the eclogite examined it was difficult to find even a small residual nucleus of clear garnet, while in some of the much-weathered specimens the garnets have suffered little or change. Individuals are frequently found in contact, thus mutually interfering with one another's development. Where circumstances have been favourable crystallographic outline is shown.

The alteration displayed by the garnet has already been referred to when describing the basalt. It may be thus summarised:—

a. Loss of transparency, often amounting to absolute opacity in moderately thick slices.

b. Development of strong colouration in the ground-mass, passing through various shades of grey, green, yellow, brown, or red to black. By reflected light the more opaque portions are dirty-white.

c. Loss of isotropism, the altered material being distinctly doubly-refracting.

The dominant colour of the altered garnets is a rich red-brown. They are not appreciably dichroic, and generally deepen in colour towards the periphery, which is usually marked by a black granulated skin.

* *Op. cit.*, p. 248.

NOTE.—Special difficulty was experienced in slicing the eclogite on account of a tendency to strip the wheel, and of its exceptional hardness in places. No altogether satisfactory explanation of this has yet been suggested; but it is exceptionally interesting to learn, just as this number is going to press, that Sir W. Crookes has isolated a minute diamond by dissolving a small portion of one of the specimens of South African eclogite described by Prof. Bonney. Proc. Roy. Soc., LXVII, No. 441, p. 483.

The coloured ground-mass is largely occupied by dusky bifurcating growths, radiating from the centre of the mass (Pl. X, Fig. 1). Tangential sections thus give a cellular appearance, while others are feathery; or the effect may be one of streakiness only. The outer zone is sometimes of a different character to the interior, constituting a radially fibrous shell—the kelyphite rim. The fibrous nature of the coloured ground-mass itself is sometimes well brought out between crossed Nicols. That the alteration has resulted in an expansion of the original mass is evidenced by veins of altered material ramifying from the garnet through the pyroxene and felspar; by the shattering of these latter minerals in the vicinity of the garnet; and, perhaps, by the crowding-together of the altered garnets (Pl. X, Fig. 3).

Enclosures of pyroxene and felspar are occasionally present.

Pyroxene (omphacite).—The most abundant constituent. Colour, grey or pale greenish-brown, but very slight in all cases. Cleavage-flakes (orthopinacoidal) show brownish to greenish axis colours.

Cleavage usually slight or entirely absent. The characteristic prismatic cleavage is, however, sometimes distinct enough, and there is, perhaps, a tendency for this development of cleavage to manifest itself particularly in individuals wedged in between altered garnets; it may be—as suggested to me by my friend, Mr. W. G. Woolnough, of the University of Sydney—that the pressure occasioned by the expansion of the garnet, consequent on alteration, has set up the cleavage (Pl. X, Fig. 2). Moreover, the cleavage sometimes terminates at a crack. In addition to the prismatic cleavage, strong, broad parting lines are sometimes seen. The index of refraction is near that of olivine, giving rise to a strongly-pitted surface. Crystallographic form is never shown.

The extinction-angle, measured from the single cleavage, reaches 43°.*

Double refraction is fairly high. Cleavage-flakes show straight extinctions, transverse partings, and the oblique emergence of an optic axis. From the straight extinctions given by these cleavage-flakes, it is evident that an orthopinacoidal or basal parting is present in the pyroxene.† It is decidedly diallagic in character. By Wadsworth's method‡ the optical sign is positive.

Schillerisation is not present.

---

* In a large grain from the sand an angle of 45° was obtained.

† Similar results were given by pyroxene grains from the sand. Mr. W. G. Woolnough, B.Sc., has shown me a flake obtained by him from a grain from the sand, that showed the emergence of an acute bisectrix, the axial angle being wide, and dispersion apparently rhombic (red less than violet). Examined with a lens, this flake appeared to be wedge-shaped. It seems probable that this was an accidental fracture from the ortho-diagonal zone.

‡ American Geologist, 1898, XXI, pp. 173, 174.

An examination of grains carefully separated from the crushed rock by heavy solutions and by hand-picking gave the following results:—Colour, emerald green; streak, white; lustre, vitreous; specific gravity, practically identical with that of Arendal coccolite;* hardness, 6 or a little over; fusibility, easy; borax,† chrome-green bead; salt of phosphorus, no definite result.

Not appreciably acted upon by HCl.

No alteration is apparent, but the cracks have been occupied by an anisotropic yellow or green product, identical in character, and in direct connection with that developed in the altered garnet (p.).

Enclosures of cyanite, felspar (?), and altered garnet (?) were noted. Rutile has not been detected.

An analysis of pyroxene grains carefully picked from a weathered specimen of eclogite, kindly made for me by Mr. H. P. White, Assistant Analyst, Department of Mines, resulted as follows:—

SiO_2	45·92
TiO_2	trace
Al_2O_3	12·03
Fe_2O_3	2·24
FeO	1·73
MnO	trace
MgO	13·30
CaO	22·73
Na_2O	1·19
K_2O	·32
H_2O (100°+)	·66
CO_2	·39
V_2O_5	trace
	100·51

Specific gravity, 3·338.

Cr_2O_3 was found to be entirely absent. The carbonic anhydride is combined with lime. As a result of many trials, Mr. White found that the lime-carbonate exists as a pellicle on the outside of the grains, and points out that carbonic anhydride is entirely absent in sounder pieces of rock. It is evident that weathering has resulted in the formation of a very thin skin of lime-carbonate. The Fe_2O_3 is probably partly due to the presence of the thin veins of alteration-material referred to above. By comparison with the numerous analyses quoted by J. D. Dana in the sixth edition of his System of Mineralogy, the nearest analogues

* Mr. H. P. White has since determined it precisely as 3·338.

† Similar experiments with pyroxene from the sand gave more decided results.

are the varieties classed by him as omphacite. The present analysis shows (*a*) less silica, (*b*) more alumina, (*c*) a higher CaO : MgO ratio than those quoted by Dana, but the difference is not great. The work of Hillebrand and others has shown that vanadic oxide is frequently present in minerals of this class, and is in many cases the cause of colouration,* and White is of opinion that it is so in the present instance. The percentage of iron oxides present is exceptionally low.

Felspar.—Less abundant than the garnet or the pyroxene; clear and glassy in all but one or two much-weathered specimens; refractive index (by Becke's method), above that of the Canada balsam; cleavages, two sometimes evident, one fairly good, the other much less so; extinction-angle measured from the best cleavage, very high; twinning, not often present, but a fine striation occasionally.

Cleavage-flakes gave high extinction angles measured from the edges, and an optic axis emerging obliquely.

Schillerisation is not present.

Grains carefully separated from the crushed rock, gave results as follows:— Specific gravity, greater than labradorite; fusibility, easy; flame results by Czabo's method, more basic than labradorite. They were slowly attacked by HCl.

From these and the optical results the felspar would appear to be the variety sometimes known as bytownite; a conclusion which is borne out by a study of the analyses (see below).

Inclusions of both garnet and pyroxene occur. Rectilinear outlines are sometimes present.

Shattering is frequent, but there is no indication of optical strain. The cracks may be occupied with alteration-products from the garnet, as in the case of the pyroxene. The boundaries are sometimes outlined by the same alteration material, as if the expansion of the garnets had given rise to a general loosening of the rock. Cracks so filled may also radiate outwards through the felspar from inclusions of garnet.

Locally in the rock the felspar may be fairly plentiful; elsewhere it is scarcer or interstitial only.

Cyanite.—Much less abundant than the other constituents, but nevertheless always present. It occurs as colourless granules, sometimes enclosed in pyroxene or garnet, sometimes surrounded by a confused grey or yellow zone, the exact nature of which is somewhat obscure. This zone sometimes takes the form of an aggregate of triclinic felspar merging into the cyanite in such a way as to suggest

* A non-aluminous pyroxene, coloured by vanadium, from beyond Lake Baikal has received the special name of *Lavrofite*.

the possibility of the former having sometimes resulted at the expense of the latter : this can be traced in all stages of transition down to complete absorption (*i.e.*, apparently) of the cyanite. The appearance of these areas is very peculiar at times, being suggestive of a foreign origin. There is, moreover, a resemblance between those in which cyanite is absent and the chondritic structure of meteorites. (Pl. XI, Figs. 2, 3.)

The single and double refraction are very high. Extinction with the edges, when these are present, is oblique. External form is best shown in the crystals enclosed in pyroxene, in which case there may be two parallel edges with rounded terminations, or cross-sections showing one longer and two shorter pairs of sides. (Pl. X, Fig. 4.)

Quartz.—Doubtfully present.

Composition.

An analysis of a picked piece of the soundest eclogite, by H. P. White, resulted as follows :—

SiO_2		43·05	717
Al_2O_3		20·74	203
Fe_2O_3		4·55	28
FeO		4·08	57
MgO		7·06	176
CaO		15·30	273
Na_2O		1·59	26
K_2O		·21	2
H_2O	100° C.	·50	
	above 100° C.	2·97	165
TiO_2		trace	
SO_3		nil	
P_2O_5		·02	
V_2O_5		trace	
MnO		·23	3
		100·30	

Special tests proved the absolute absence of chromium. The molecular ratios of the principal oxides are placed to the right of the weight percentages (in heavy type). The Mügge† and Brögger‡ diagrams, based on this analysis, will be found in Pl. XI (figs. 1, 2). From the former the preponderance of lime and the great excess of alumina, over and above that required to satisfy the alkalies, is apparent. Considering that the composition of the garnet and the pyroxene have been ascertained by actual analysis, the proportions in which the component minerals exist in the eclogite should be readily calculated. The results obtained in this way do not, however, coincide with those observed, the proportions of anorthite and pyrope

† N. Jahr. b. für Min., 1900, I. p. 100.
‡ Journ. Geol., VIII, No. 1, p. 11.

being respectively greater and less than a study of the thin slices would have led one to anticipate. Moreover, the amount of felspar visible in the powdered rock does not suggest anything like a percentage of 29 by weight, as given by calculation. After many trials it was decided to make the following assumptions and deductions:—

1. The manganous oxide being all contained in the pyrope affords a basis for calculation.
2. The magnesia not required to satisfy pyrope gives the amount of omphacite.
3. The balance of soda not required for omphacite represents albite molecules.
4. The balance of lime not required for omphacite represents anorthite molecules.

Since this estimation depends entirely upon the amount of manganous oxide present in pyrope, an error in this determination affects the proportions of omphacite and of anorthite. The low results obtained for pyrope lead to a suspicion that the analysis of that mineral may not be entirely reliable.

It is not certain what alteration products are present. Assuming that the surplus alumina is in the form of cyanite, the surplus silica in the form of quartz, and that the bulk of the ferric oxide is combined with ferrous to form magnetite molecules, the whole of the constituent oxides can be fully accounted for with the exception of a few molecules of ferrous oxide and a large proportion of the water. As the composition of the alteration products is not known, it may well be that the surplus silica and alumina do not exist in the free condition respectively, but are combined with water as a hydrated silicate.

Calculating from the molecular ratios, and using the percentage of manganous oxide quoted by Curran (see page 32) as a basis, combined with the knowledge obtained by a study of the thin sections, the constitution in weight percentages of the eclogite is as follows:—

Pyrope,	5·7		Pyrope,	5·7
Omphacite,	47·2		Omphacite,	47·2
Albite,	8·9		Albite,	8·9
Anorthite,	20·4		Anorthite,	20·4
Cyanite,	4·7	or,	Cyanite,	17·8
Magnetite,	5·1		Magnetite,	
Quartz,	4·3		Quartz, (?)	
Unaccounted for,	3·7		Alteration products,	
	100·0			100·0

The alternative statement is perhaps to be preferred. The ratio between the albite and anorthite molecules is 34 : 73, corresponding very nearly to a felspar $Ab_1 An_2$, a result in agreement with the optical determinaton, viz., bytownite, with a tendency to the labradorite side. Taking the modern view that bytownite is a mixture, the analysis would point to a labradorite with an admixture of anorthite.

Conclusion.

Apart from the comparative rarity of the rock eclogite, and of its not having been recorded—so far as I am aware—from Australia before, the present occurrence has a very special interest, arising from the work of Prof. T. G. Bonney, F.R.S., and Sir W. Crookes, F.R.S., upon the matrix of the diamond in South Africa. Prof. Bonney brings forward* the strongest evidence that the parent-rock of the diamond at Kimberley is the eclogite-rock, boulders of which occur in the breccia-pipes there. As has been already said, evidence exists that diamonds have been found in the Ruby Hill breccia; but the occurrence of masses of eclogite in a breccia-pipe would in itself justify attention. The general resemblance between the Ruby Hill breccia and the Kimberley "blue-ground" has been already referred to. The eclogite of Kimberley, so fully described by Prof. Bonney,* consists essentially of chrome-diopside and pyrope; that from Ruby Hill contains felspar and cyanite in addition. The optical resemblance between the pyroxene of the two rocks respectively is very close.† The clino-pinacoidal cleavage does not seem to be so strongly developed in the Ruby Hill variety; in other words, it is rather more diallagic in character. J. D. Dana‡ quotes two analyses of chrome-diopside from the South African diamond-fields, which show—(*a*) an almost entire absence of alumina, (*b*) the presence of nearly 3 per cent. of chromic acid. There is thus a chemical difference between the varieties of pyroxene from the two localities.

It may be noted in conclusion, that enclosures of basic character are by no means uncommon in the basalts traversing or overlying the Hawkesbury Formation. Thus, boulders of gabbro occur in this way at the Pennant Hills Quarry, Dundas, near Sydney, and gabbro also occurs in olivine-basalt from Glen Alice, Capertee. Colourless pyroxene, resembling that of eclogite, has been detected on basalts from Mount Wilson, Rooty Hill, Thirlmere, and Seal Bay (Long Bay) near Sydney. In the nepheline basalt of Burragorang a pyroxene containing picotite has been noted. At Bulli a basalt dyke contains large lumps of an aggregate of olivine, hornblende, and picotite. It would thus appear that masses of holocrystalline basic rocks must exist at no great depth in this portion of Australia.

My best thanks are due to Messrs. H. P. White and W. G. Woolnough, B.Sc., for assistance kindly rendered.

* The Parent-rock of the Diamond in South Africa. Proc. Roy. Soc., LXV, 417; also Geol. Mag., 421, pp. 309-321.
Additional Notes on Boulders and other Rock Specimens from the Newlands Diamond Mines, Griqualand West, Proc. Roy. Soc., LXVII, 441, p. 475.

* *Op. cit.*

† The following is a summary of the principal characters of the South African pyroxene, as given by Carvill Lewis (Genesis and Matrix of the Diamond, pp. 21-22):—*Colour*, fine emerald-green; *Specific gravity*, 3·267; easily *fusible*; *pleochroism*, very slight; *cleavages*, parallel to $\infty P\breve{\infty}$, $\infty P\bar{\infty}$ and OP. *Extinction* on $\infty P\bar{\infty}$, 39°; ortho-pinacoidal cleavage-flakes show in convergent light the emergence of a single axis, similar to that given by diallage.

‡ System of Mineralogy, Sixth Edition, p. 359.

VII.—Nepheline-Basalt from the Capertee Valley; by GEORGE W. CARD, A.R.S.M., F.G.S., Curator and Mineralogist.

THE specimens which form the subject of this note were collected by Mr. J. E. Carne, Geological Surveyor, and his assistant, Mr. M. Morrison, during their recent survey of the Boghead deposits of the Capertee Valley.*

The district in question comprises an area of Hawkesbury (Triassic) strata, which have been cut through by the valleys, exposing the underlying Permo-Carboniferous System. The Hawkesbury Sandstone mountains are in places capped by basalt and dolerite.

The nepheline-bearing rocks in question have been described to me by Mr. Carne as being undoubtedly intrusive in the Permo-Carboniferous strata exposed in the Capertee Valley; but as they have not been found passing up into the overlying Hawkesbury beds, and are petrographically distinct from the surface-flows, he considers that they may be of Pre-Triassic age.

The best specimen (4560 in the Survey collection) represents a knoll, near J. A. Nicholson's farm, the Main Nile (west side of Umbiella Creek), Glen Alice, Por. 30, Ph. Tayar, Co. Roxburgh, twenty-seven miles by road from Capertee.

The rock is compact, blackish-grey in colour, showing translucent or flesh-coloured greasy-looking blebs of nepheline, &c. Specific gravity, 3·02.

After crushing and sizing, a number of the light-coloured grains were picked out and placed in a solution of methylene iodide that just floated typical nepheline from Vesuvius; some quickly sank, while others settled down more slowly. Flame reactions for potassium and sodium were obtained. The fine powder was energetically acted upon by strong HCl, with effervescence and subsequent gelatinisation. The solution gave a strong sodium flame, and contained much iron and lime, but apparently very little magnesia; it also gave a good phosphoric acid reaction. The specimen is so very small, that it was not considered advisable to separate the different minerals for individual examination; but the above reactions, combined with the microscopical evidence to be given immediately, point to the presence of nepheline and olivine among these small phenocrysts.

Under the microscope the slides examined show phenocrysts of idiomorphic olivine and augite in a holocrystalline ground-mass, consisting of augite of the second generation, some granular olivine, and interstitial nepheline.

* Until very recently no nepheline-bearing rocks had been recorded from New South Wales. Prof. T. W. E. David, F.R.S., has described (Proc. Linn. Soc. N.S.W., XXVI, i, p. 30) a dyke-rock from the Valley of the Snowy River, provisionally classed as phonolite, in which nepheline in idiomorphic glassy crystals, sometimes of macroscopic dimensions, is an abundant constituent. Nepheline-bearing rocks are well-known in Tasmania, and nepheline-basalt has been recorded by Mr. B. Dunstan from the Dawson River District, Queensland, but not yet described.

Olivine.—Fresh, but often iron-stained; six-sided sections common; frequently corroded and shattered. This iron-staining, and the small percentage of magnesia found in the allied rock from Sapling Flat, point to a hyalo-siderite variety.

Augite.—Two generations—

(*a*) *Phenocrysts.*—Idiomorphic, generally untwinned; purple-brown pleochroism; zoning common, the external zone at times distinctly purple: whether coloured or not, the different zones show a difference in their extinction angles, and also in their bi-refraction. Some large individuals show a well-marked zone of resorption. The central portions are sometimes darkened by opaque granular matter.

(*b*) *Ground-mass.*—Small rods and grains seen to be idiomorphic under high magnification; slightly purple in colour.

Nepheline.—Interstitial, clear. Indications of crystallographic form are seldom seen, so that determinations of extinction-angles cannot be made with any certainty. Traversed by colourless needles, irregularly arranged, and more or less anisotropic. Inclusions of augite and iron ores sometimes present. An apparent rectangular cleavage, along which slight alteration has taken place, can be noticed. Refractive index less than that of the balsam. Bi-refraction very weak, but can generally be made out under sensitive light. An effect similar to the multiple twinning of plagioclase is sometimes shown. Brownish-yellow staining visible in places. The mineral is uniformly distributed on the whole. Occasionally large areas, enclosing much augite and olivine, are uniformly orientated: the frequency with which these areas are perfectly isotropic, suggests the probability of primary analcite being present.

Cancrinite.—Occasional grains resembling nepheline, but for the higher double refraction (yellow of the 1st Order), are very possibly cancrinite. The presence of this mineral would help to explain the ready effervescence of the rock powder in cold HCl, but secondary calcite is also present.

Iron Ores.—Magnetite specks throughout.

Pleonaste.—Deep black margin. One piece encloses olivine. It seems most probable that these are allogenic particles.

Quartz.—Allogenic grains, with zone of alteration at the contact with the matrix.

Calcite.—Alteration product.

The presence of melilite is suspected, but not proven.

Throughout the rock occur yellowish- or brownish-white opaque spots, sometimes with a red centre; these have no definite crystallographic outline. There are also small transparent red grains that are sometimes square in outline. In no case do these show high refractive effects, so that they cannot be perofskite; their nature has yet to be determined.

From a little knoll, rising up from the swamps, three or four miles down the creek (N.E. corner of Por. 10, Ph. Coorongooba, Co. Hunter) Mr. Carne has collected similar specimens [4544]. These contain felspar-microlites in the base, but otherwise resemble the Sapling Flat rock described below. A clear colourless material, both isotropic and anisotropic, may represent nepheline or analcite.

From a small patch, a few square yards only in extent, at Sapling Flat, Por. 69, Ph. Goollooinboin, Co. Roxburgh, Capertee Valley, comes a similar rock [3950] in general characters, but with nepheline less in evidence than that just described.

This rock is grey-black in colour, weathering to light-brown. Compact, showing but little structure under a lens. Olivine phenocrysts weathering to an ochreous material. Enclosures of quartz, sandstone, and shale are abundant. Specific gravity, 3·01.

Under the microscope phenocrysts of olivine and augite are seen in a granular holocrystalline ground-mass of the same minerals, with some interstitial nepheline. The olivine is red when weathered; from this and the small amount of magnesia shown by the rock-analysis, it would appear to be hyalosiderite variety. The nepheline is interstitial in character, and more or less local in distribution: it is revealed by staining. The general microscopic description of this rock agrees with the preceding.

The soundest piece available of this rock was analysed by Mr. J. C. H. Mingaye, F.I.C., with results as follow*:—

The rock is partly soluble in acids with evolution of CO_2.*

	I.	II.
SiO_2	39·920	665
Al_2O_3	11·257	110
Fe_2O_3	4·243	26
FeO	11·005	153
MgO	8·007	200
CaO	8·910	157
Na_2O	3·183	51
K_2O	2·695	29
H_2O at 100°	0·400	...
H_2O above 100°	2·150	...
TiO_2	1·020	13
CO_2	6·820	155
SO_3	0·302	4
P_2O_5	0·409	3
V_2O_5	trace.	
MnO	0·110	1
	100·431	

I. Analysis of the rock.

II. Molecular ratios calculated from I.

* It is unfortunate that the more typical rock from Glen Alice was not recognised until sometime after; an analysis by the latter would, naturally, have given more useful results.

* If cancrinite be present a portion of this CO_2 would belong to the unaltered rock; in any case the bulk of it will be combined with CaO, resulting from the decomposition of primary constituents.

It will be noticed that the lime-ratio is rather low for rocks of this class. Moreover, the ratio Na_2O: K_2O is barely 2: 1, while in pure nepheline it is 3 : 1. The Mügge and Brögger diagrams corresponding to this analysis will be found on Plate XI (figs.). From the Mügge diagram the insufficiency of the alumina to satisfy the soda is evident.

NOTE.—Mr. Carne has since collected, to the east of Lue, a series of nepheline-bearing rocks which will shortly be described. One of these very closely resembles the Snowy River rock referred to above.

VIII.—Mineralogical Notes, No. 7: by GEORGE W. CARD, A.R.S.M., F.G.S., Curator and Mineralogist.

THE following occurrences of minerals in New South Wales may be recorded—some for the first time. Those in which no reasonable doubt exists as to the exact locality are indicated by a prefixed* :—

**Aegyrine.*—Microscopical crystals in a phonolitic-nephelinite dyke-rock. Near Hedley Tarn, Snowy River.† Also in a similar rock east of Lue.

**Alum.*—Variety undetermined. Half-way up the Peak, Upper Burragorang. The mineral forms a layer of matted crystals in the Permo-Carboniferous beds.

Antimony (Native).—Massive with a crust of oxide. Twenty-five miles north of Armidale.

Apatite.—Small crystals of macroscopic size, in leucitite, from Capitan, Byrock.

Axinite.—With quartz and epidote. Colour, grey-violet; structure, lamellar; faces, slightly curved. Manilla District.

**Barytes.*—Clear, transparent, colourless masses showing good cleavage. Near Leadville.

**Bastite.*—In serpentine, from Port Macquarie and neighbourhood.‡ It appears as if the Port Macquarie serpentine had resulted from the alteration of a rock rich in rhombic pyroxene.

**Berthierite.*—Rivertree; near Inverell; Parkes District.

† Prof. T. W. E. David, F.R.S., Procs. Linn. Soc. N.S. Wales, XXVI, Pt. 1, p. 30.
‡ Collected by F. D. Power, Esq., F.G.S., while endeavouring to trace the original rock from which the Port Macquarie serpentine was derived.

**Chalybite.*—In an argentiferous lode-stuff, consisting of quartz, galena, mispickel, zinc-blende, &c. Also massive. Yerranderie, and other silver-mines, The Peaks, Upper Burragorang.

**Chrysocolla.*—Encrustations and small greenish-blue botryoidal forms on ferruginous material. Chandler River, Emmaville.

Columbite.—A small piece not quantitatively determined as yet. The specimen was received from the Western District, and may have come from the Barrier Range, but the exact locality is not yet known.

**Cosalite.*—A large block was found some time ago at Duckmaloi, in the Oberon District. The block appeared to be a fallen one, and its source was not ascertained. The mineral had the characteristic jamesonite structure, and some specimens contained gold. The gangue is quartz associated with copper-pyrites.*

Covellite—

(1) In white quartz. Near Broken Hill.

(2) With copper pyrites in quartz. Kirkiamah Station, twenty-four miles from Young.

**Cyanite*—

(1) Blue characteristically-bladed crystals in copper-stained mica-schist. Alma Mine, five miles from Broken Hill.

(2) A massive white, or somewhat fibrous variety. Dartmoor Copper-mine, Cooma.

**Delessite.*—Wentworth Extended Mine (800-ft. level). Lucknow.

**Diopside* (omphacite).—Emerald-green variety, containing traces of vanadium, to which the colour is probably due.§ Ruby Hill, Bingera.

**Enhydros.*—Fine specimens, up to twelve inches in diameter, were once found at one place only in the Kingsgate Bismuth Mines. One or more of these are known to have contained water.‖

Ferro-calcite.—In basalt. Boggabri. Also from Tullamore.

Glaucophane.—In glaucophane mica-schist.¶ Not in tangible crystals, but in sufficient abundance and size to impart a silky lustre and blue colour to the rock. New England (possibly Gilgai, near Inverell).

**Hypersthene.*—Abundant in a holocrystalline rock. Pollock's Gully, Kiandra.

* For Analysis see Ann. Rept. Dept. Mines N. S. Wales for 1899, p. 203.

§ See page 35.

‖ Information kindly given by W. H. Yates, Esq.

¶ See page 47.

Jade (nephrite).*—Although undoubtedly jade, it is of little or no value, as the effect when polished is very poor. Wentworth Mine, Lucknow.

Marcasite.—Crystallised. Lobbs' Hole, Yarrangobilly.

Martite.—Near Byng; Parkes; and other places.

Mimetite.—In a pulverulent material, containing coarse crystalline gold, said to have been obtained by washing rubble from a shaft. Distinct crystals, some clear, colourless, and hexagonal. Parish Wyangle, Tumut District.

Molybdic Ochre.—In cobalt ore. Carcoar. *On white quartz with molybdenite, in Mount England, Deep Creek.

**Molybdenite.*†—Very fine crystals. ‡Kingsgate Bismuth Mine. In large flakes. Bolivia.

Montanite.—A massive variety, containing manganese and showing flakes of unaltered tetradymite. Nanima Bismuth Mine, near Yass.

**Nepheline*—

(*a*) Abundant in the Snowy River rock, in which the ægyrine referred to above occurs. Hand specimens of the rock show abundant perfectly formed (prism with modified summit) glassy little crystals. Also, in a similar rock from Ph. Barigan.

(*b*) In nepheline basalt. Capertee Valley.

It is present in microscopic crystals in a nepheline-basalt capping the mountain known as The Peak, Upper Burragorang.

Its presence (microscopic) is also suspected in a lamprophyre (?) from the base of Mount Dromedary.

Opal—

(*a*) Translucent, chrome-green variety, passing into brown common opal. A beautiful stone, polishing well. Port Macquarie.

(*b*) Amygdales of precious opal in melaphyre. Near Ballina.

**Pyrargyrite.*—In the sulphide ore. Burragorang Silver Mines.

Pyromorphite—

*(1) W. Groups of acicular brown crystals on galena. Wallah Wallah Mine, Rye Park.

(2) Small transparent citron-coloured crystals. Kingsdale, Goulburn.

*(3) Massive green variety. Four miles north-east of Yass.

(4) Yellow Mountain, Condobolin District.

(5) Cooma.

** For analysis by J. C. H. Mingaye, see Ann. Rept. Dept. Mines, N. S. Wales, for 1899, p. 203.
† Molybdenite in specks is of very common occurrence in granite from different parts of the Colony
‡ In the collection of W. H. Yates, Esq.

Rhodonite.—Massive variety with magnetite. Eight miles north of Lyndhurst Also in various districts of New England.

**Rutile.*—Small crystals in wash-dirt from a tunnel. Uralla.

**Scheelite*—

(1) Brownish variety with quartz, one and a half miles west of Tuena.

(2) In pannings from conglomerate. Goulburn District.

(3) With hornblende. Queanbeyan.

Scorodite. Amorphous with quartz—

(1) Boona Tank.

(2) One and a half miles south of The Alberts, Dandaloo. This variety is sometimes auriferous.

(3) Small crystals occupying crevices on quartz. Near Mount Oxley.

Selenite.—Fine crystals. Mount Scott, near Talbragar.

**Silver (Native).*—The finest specimens yet recorded from this State have been found at the Burragorang Silver Field. The native silver occurs in a vein-stuff consisting of galena, chalybite, mispickel, and quartz. The Yerranderie Mine yields leaf-like specimens larger than one's hand.

**Sphene.*—In many granites and syenites. Pretty little macroscopic crystals can be seen in granites from Moonbi and Wilson's Downfall respectively.

**Stannite.*—Very fine, massive pieces in argentiferous sulphide ore. Conrad Mine, Bora Creek, Inverell.

Sulphur (Native)—

(1) On galena. Consols Mine, Broken Hill.

(2) In cavities in lode quartz. Eight miles from Coolamon.

(3) With quartz and mispickel. Herbert Park, Armidale.

**Talc.*—Pale-green foliated variety. Gilmandyke Mine, Rockley.

**Uralite*—Microscopically in andesites from Lyndhurst, Blayney, Carcoar, Cadia, Orange, &c.

Valentinite.—Acicular radiating crystals in a somewhat siliceous ore. Ulmarra, Clarence River.

Vivianite.—Well-crystallised on pyrrhotite. Milburn Creek Copper Mine.

Zircon.—Macroscopic crystals in quartz-diorite. Mount View, near Cessnock.

IX.—Chemical Notes on Glaucophane Schists, from Australia and New Caledonia: by HAROLD P. WHITE, F.C.S., Assistant Analyst.

ANALYSES of only two specimens of this comparatively rare rock are given in this paper.

Quartz-glaucophane Schist, Ollard, near Pam, New Caledonia, collected by F. D. Power, Esq., F.G.S., early in 1901.

"A silky-looking blue rock, in which acicular crystals of *glaucophane*, sometimes several millimeters in length, can be abundantly seen. Not very fissile. Under the microscope the mineral constitution is seen to be very simple, the bulk of the rock being made up of *glaucophane* needles, either closely felted or (not so commonly) embedded in *quartz*. An opaque-white alteration product is also present. The *glaucophane* is thoroughly typical as regards its optical properties, the violet-blue and greenish-yellow axis-colours producing a particularly beautiful effect."

The analysis is shown under No. I.

Professor A. Liversidge, F.R.S., has described glaucophane from the Balade Mine, Onegoa, New Caledonia, collected by Mr. Pryor, F.G.S. This mine is in the same district as that from which Mr. Power procured his rock, but the specimens do not correspond. The Balade mineral is described by Professor Liversidge as being intimately associated with *mica* and *garnet*, in addition to quartz. One of Mr. Pryor's specimens was crystallised. Analyses of picked glaucophane are given in the work cited.*

Mica-glaucophane Schist, New England District of New South Wales. The exact locality is not yet known; it may, very probably, be Gilgai, near Inverell.

This was identified by Mr. G. W. Card, A.R.S.M., to whom I am indebted for the petrographical notes in this paper.

"A somewhat fissile rock, showing abundance of white mica on the divisional planes; cross-fractures have a silky lustre, and wavy surface of a distinct blue tint. Under the microscope it is seen to consist of abundance of small individuals of *glaucophane*, with overlapping cross-sections, and much *white mica* in broad plates. As accessories *garnet*, *epidote*, and probably *cyanite*, are present in small amount. A little magnetite and a good deal of green material occur as alteration products."

* The Minerals of New South Wales, etc., London, 1888, pp. 288-9.

The analysis is shown under No. II. With these, for the purpose of comparison, I give an analysis of a Mica-glaucophane Schist, Cape Skarbeli, Hermonpolis, Syra, Henry S. Washington, analyst.† It is shown under No. III.

	I.		II.		III.
H_2O 110° — ...	·18	.....	·19	.....	·22
H_2O 110° + ...	·97	.....	1·46	.....	·98
SiO_2	55·74	.....	48·10	.....	58·26
Fe_2O_3	4·10	.....	2·50	.....	3·44
FeO.....	6·44	.....	9·81	.....	4·63
Al_2O_3	13·24	.....	18·60	.....	16·21
MnO	·07	.....	·11	.....	trace.
CaO.....	2·63	.....	3·69	.....	3·82
MgO	6·86	.....	7·45	.....	4·99
K_2O.....	·15	.....	1·79	.....	·39
Na_2O	7·47	.....	4·60	.....	5·36
TiO_2	2·01	.....	1·16	.....	1·37
CO_2	nil.	.....	nil.	.....	.....
SO_3	trace.	.....	·08	.....	.....
P_2O_5	trace.	.....	·19	.....	.....
	99·86		99·78		99·67

Washington has analysed a considerable number of glaucophane schists from various parts of the world, and in a very interesting paper,‡ in which he refers to the work of other investigators, he discusses the various analyses and arrives at certain general conclusions, quotations from which are given here, as I think that my analyses form a slight addition to the work just mentioned.

"It is at once evident that these rocks are divided into at least two main groups. One, the larger, is basic, with SiO_2 ranging only from 46 to 49·7; the other is very acid, with SiO_2 ranging from 74·5 to 82·5. These two seem to be very sharply separated, a possible third intermediate group being represented by only one analyses with SiO_2 58·3.*

"*Basic group.*— . . . It is seen that they are of fairly uniform composition in most respects. Al_2O_3 in most of them is rather low, from 13 to 15. . . . Iron oxides are high in all, and FeO uniformly surpasses Fe_2O_3 (molecularly). . . . MgO varies from 4·1 to 8·2. . . . CaO shows the most striking behaviour, running from 4·4 to 5·8 in some, and then with a break from 11 to 13 in others. . . . Na_2O remains very steady, varying only from 1·1 to 3·7, while K_2O is present, as a rule, only in traces, being above 1 per cent. in two cases. . . . CO_2 is often quite absent, and again high. H_2O is, of course, present in considerable, but varying amount. TiO_2, when determined, is always high. . . . P_2O_5 and MnO are present only in traces."

† A Chemical Study of the Glaucophane Schists: Am. Journ. Sci., Fourth Series, Jan., 1901, XI., No. 61, p. 55.

‡ Op. cit.

* *Op. cit.*, p. 54.

In comparing this basic group with igneous rocks, Washington says*:— "Chemically these closely resemble the composition of the rocks of the gabbro family, and are apparently divisible into two sub-groups, one high in Ca O, the other low in it."

The mica-glaucophane schist from New England (II) decidedly belongs to this basic group. It will be noticed that the Al_2O_3 is rather high, but it may be pointed out that Washington found, in four analyses, Al_2O_3—17·34, 19·74, 16·88, and 18·36.† The potash also is high, and this in conjunction with the high alumina points to the presence of a fair quantity of muscovite.

The quartz-glaucophane schist from New Caledonia is interesting, as it proves to be, I think, another member of the intermediate group. Of this group, Washington gives one analysis (*vide* No. III). It will be noticed that his analysis is of a mica-glaucophane schist. He remarks on the division, by Von Foullon and Goldschmidt, of the glaucophane shists of Syra into two groups, in which the blue hornblende was associated either with epidote or mica, that "it does not recognise fully enough the fact that the mica-glaucophane schists tend to become highly acid through the increase in quartz and decrease in mica."‡

X.—The Graptolites of New South Wales, in the collection of the Geological Survey: by T. S. HALL, M.A., Melbourne University.

[Plates XII—XIV.]

THE present paper deals with the results of my examination of the whole of the New South Wales graptolites in the collection of the Geological Survey of that State, which were kindly forwarded to me for examination by Mr. E. F. Pittman, Government Geologist. The collection comprised some five hundred slabs, and occupied over thirty square feet of drawer space.

The collections from Stockyard Creek, Currowang, Tingaringi, and Lawson, were briefly dealt with by Mr. W. S. Dun,* and the results were incorporated by Mr. J. E. Carne in his report on the geology of the district where he procured

* *Op. cit.*, p. 59.
† *Op. cit.*, p. 55.
‡ *Op. cit.*, p. 33.
* Rec. Geol. Survey N. S. Wales, v., p. 124.

the specimens.† The stratigraphical position of the containing beds is, as Mr. Dun has pointed out, near the horizon of the graptolite yielding series of North Eastern Victoria, in other words it is Upper Ordovician. At present our knowledge of the distribution of the graptolites in Australia is not sufficient to enable us to do more than to divide off the Upper Ordovician beds characterised by Dicranograptidæ from the Lower Series. Ill-preserved graptolites are not easy of determination, and a prolonged examination has led me to differ, in many instances, from the provisional identifications of Mr. Dun, without, however, in many cases, enabling me to do more than substitute other provisional ones.

As I have attached names, sometimes, it is true, only generic, or it may be even only family ones, to everything which I think can be identified, it will be understood that where our lists are not in harmony I believe the species signified by Mr. Dun are not present, and the record should be erased. Since I have the whole of the material on which Mr. Dun has worked, I think this statement is necessary as a guard against future confusion, and I make it the more readily as the suggestion that I should do so came from Mr. Dun himself, and it is to his initiative that I owe the opportunity of making the examination, for which my warmest thanks are due to him.

In this conjunction it may be mentioned that I believe certain species identified from Victorian rocks by the late Sir F. M'Coy,‡ namely, *Diplograptus mucronatus* J. Hall, *D. rectangularis*, M'Coy, and *D. palmeus*, Barr, are not those species, the two latter, indeed, not occurring in Ordovician rocks at all, but being characteristic of Silurian age. What the true names of these fossils are, I am not at present prepared to state definitely.

The presence of graptolites at Orange was announced by Mr. H. G. Smith, who exhibited specimens collected by Mr. R. H. Cambage, at a meeting of the Royal Society of New South Wales.§ The Mandurama specimens I have dealt with elsewhere.‖

The presence of graptolites at Tomingley was announced by Mr. W. S. Dun,¶ they having been discovered by Mr. F. Danvers Power, F.G.S., and additional specimens were obtained soon after by Mr. Card. The specimens obtained by these two gentlemen are included in the present collection.

---

† Ann. Rept. Dept. Mines and Agric. N. S. Wales for 1896 [1897], p. 101.

‡ Prodromus Pal. Victoria.

§ Proc. R. Soc. N.S. Wales, 1899, xxxiii, p. xli.

‖ Rec. Geol. Surv. N.S. Wales, 1900, VII, Pt. i, p. 16.

¶ Dun, W. S. The Occurrence of Graptolites in the Peak Hill District. Records Geol. Survey N.S. Wales, 1898, V, Pt. iv, p. 183.

GRAPTOLOIDEA, Lapworth.

Family *Leptograptidæ*, Lapw.

Genus.—LEPTOGRAPTUS, *Lapworth*, 1873.

(Geol. Mag. 1873, p. 558).

An indistinct specimen from Tingaringi, may probably be referred to this genus

Genus—uncertain.

(Plate XII, fig. 1.)

A figure is given of a fragment which, from the disposition of its branches, seems to be referable to this family, and perhaps to the genus *Pleurograptus*. No thecæ are visible in the specimen figured.

Locality :—Stockyard Creek.

One or two specimens from Lawson may also be referred to this family, and are perhaps *Azygograptus* or else fragments of *Pleurograptus*.

Fragments of branches which apparently belong to some other members of the family also occur among the Stockyard Creek specimens.

Family *Dicranograptidæ*, Lapw.

Genus.—DICELLOGRAPTUS, *Hopkinson.*

(Geol. Mag. 1871, p. 20.)

Dicellograptus affinis, n. sp.

(Pl. XII, fig. 2, Pl. XIII, figs. 1, 2.)

Hydrosome resembling *D. Morrisi*, Hopk, as figured by that author.* It differs in the fact that the sicular aperture and its virgella are not exposed, while the lateral spines are much longer and stouter than in that species. In some specimens the pointed end of the sicula seems to project further than in the specimen here figured, but it is too indistinct to draw satisfactorily.

Thecæ very imperfectly preserved, about 10 in 10 mm. A figure of a specimen, in which the branches cross is given, and which I regard as a member of the same species as the characters of the base are identical as far as can be seen, and a very slight spiral twisting of the polypary would cause the different appearance in compression.

Locality :—Both forms are common at Stockyard Creek, and the species is doubtfully represented at Tingaringi and Currawang.

* Geol. Mag., 1871, pl. 1, fig. 2a.

Dicellograptus cf. *divaricatus*, J. Hall.

(Pal. N. York, III, 1859, p. 513, fig. 3, non. 1, 2, 4.)

(Pl. XII, fig. 3, Pl. XIII, fig. 3.)

Hydrosome stout, branches diverging at an angle of from 30° to 45°, and almost straight, about 1 mm. wide and up to 65 mm. long. No trace of sicula or virgula shown in either of the two specimens. Virgella probably represented by a small median spine. Thecæ 10 in 10 mm., with the aperture facing slightly inwards, the first eight or ten with spines arising from the middle of their length—those spines further from the sicula being the smaller. Only two specimens are present in the collection, and the thecæ are not well enough preserved to make a reference to a definite species advisable. A comparison may also be made with *Dicranograptus rectus*, Hopkinson.

Locality :—Stockyard Creek.

Dicellograptus cf. *elegans*, Carruthers.

(Geol. Mag. 1868, pl. v, fig. 8a.).

(Plate XII, fig. 4.)

Hydrosome fairly stout; the branches, at times, reaching a length of 7 or 8 mm. inclined at an angle of about 45°, slightly sigmoidally curved and furnished with basal spines. Thecæ about ten in 10 mm., the earlier being doubtfully spinose. The specimens are all distorted by pressure so that the thecal form is uncertain.

Locality :—Tomingley. Three or four specimens.

Dicellograptus spp. indet.

Several indeterminate species, mostly small, occur at Lawson and at Currawang, and a specimen is figured from Lawson which may be either *Dicellograptus* or *Dicranograptus* (Pl. XIII, fig. 4). If belonging to the latter genus it resembles *D. furcatus*, J. Hall, but is much smaller.

Genus.—DICRANOGRAPTUS, *J. Hall*, 1865.

(Graptolites, Quebec Group, p. 57.)

Dicranograptus zic-zac, Lapw., var. *minimus* Lapw.*

(Pl. XII, fig. 5.)

Specimens from Lawson very closely resemble Lapworth's species in form, but are a little larger and the base is not so attenuated. Undivided basal part

* Proc. Belfast Naturalists' Field Club, 1876-77, p. 141, pl. 6, fig. 42b, and Cat. Western Scott. Fossils, 1876, pl. 3, fig. 77a.

3·5 mm. long with four thecæ on each side. Thecæ 10 in 10 mm., those of the basal part spined as are also the first two of each of the branches. As no further details are visible, the reference to Lapworth's species is not absolutely certain.

Locality:—Lawson, two or three examples, and doubtfully present at Currawong.

Family—*Diplograptidæ*, Lapw., 1873.

Genus.—DIPLOGRAPTUS, *M'Coy*, 1850.

(Ann. Mag. Nat. Hist., 2nd series, VI.)

Diplograptus Carnei, n. sp.

(Plate XII, fig. 6.)

Hydrosome gradually expanding from the sicular end for about two-thirds of its length, and then narrowing to a rounded point, or occasionally truncate. Length, 20-30 mm.; greatest breadth, 3·5 mm. Virgula rarely perceptible. A short virgella and two lateral spines present. Thecæ straight, or in some aspects gently expanding. Apertures at right angles to the thecal length. Thecæ inclined at from 40° to 50° to the axis; 10 or 11 in 10 mm., overlapping about two-thirds their length. The species is allied to *D. truncatus*, Lapw., but differs in the form of the hydrosome, which is constant in a large number of specimens.

Locality:—Stockyard Creek, very common. Common also at Tomingley and at Orange.

Diplograptus foliaceus, Murchison.

(Murchison, Sil. Syst., 1839, pl. xxvi, figs. 7a–7g. Hopkinson and Lapworth, Quart. Journ. Geol. Soc., XXXI, 1875, p. 656, pl. 35, figs. 7a–7g.)

(Plate XII, fig. 7.)

Hydrosome attaining a length of 60 mm., 4 mm. broad, parallel-sided, with a slow tapering towards the sicular end. Virgula usually distinctly visible, rarely free for 2 mm. Virgella 1 mm. long. An apertural spine on the first two thecæ. Thecæ 8 in 10 mm., straight-sided, inclined at about 25°; apertures at right angles to the axis.

A large and striking species. Owing to the state of preservation, the virgula, virgella, and apertural spines are rarely visible in the examples before me. The thecæ are described as they usually appear in the specimens, but at times the outer and apertural margins are slightly convex, and the latter is then obliquely inclined, as shown in Lapworth's figure 7f.

Lapworth, in the reference quoted, when speaking of this "protean form," says that the least variable features in the British examples seem to be "the great length of the distal prolongation of the virgula" and the low inclination of the

thecæ. None of our specimens show any great prolongation, but with so many other points of agreement, there can, I think, be but little doubt as to the identity of our form.

Locality:—Stockyard Creek, very common; Tingaringi, common; Currawong, common; and doubtfully present at Tomingley.

Diplograptus cf. *Whitfieldi*, J. Hall.

(Pal. N.York, III, 1859, p. 516, fig. 1. Graptolites Quebec Group, 1865, figs. 29, 31, non pl. B, figs. 6–10.)

A species resembling the form described by J. Hall is present at Tomingley.

Diplograptus, spp. indet.

Some indeterminate species are common at Tomingley.

Genus—CLIMACOGRAPTUS, J. Hall, 1865.

(Graptolites Quebec Group, 1865, p. 111.)

Climacograptus bicornis, J. Hall, var. *longispina*, var. nov.

(Pal. N. York, I, p. 268, pl. 73, figs. 2a–2s.)

(Plate XII, figs. 8, 9.)

Hydrosome gradually expanding from a narrow base. Length usually about 25 mm., but sometimes reaching 50 mm. Breadth 2·5 mm. Thecæ of the usual generic type, about 8 to 10 in 10 mm. Two strong spines given off at the base and curving towards the axis of the polypary in the direction of the sicula mouth.

The present specimens are remarkable for the great development of the spines in nearly every case, but there does not seem to be any reason for separating them specifically from the well-known form, so I merely attach a varietal name, *longispina*. It is probably the commonest form at Stockyard Creek, the collection containing more than a hundred examples.

Locality:—Both varieties, *longispina* and the normal form, are common at Stockyard Creek; the normal form at Tingaringi very rare; and at Currawong, rare.

Climacograptus hastata, n. sp.

(Plate XIV, figs. 1, 2, 3.)

Parallel-sided, narrowing rapidly towards the sicula; reaching a length of about 40 or 50 mm.; breadth, 2·5 mm. Virgula 0·5 mm., broad, and may be free for about 30 mm. Virgella long and tapering, extending in some specimens to a length of nearly 20 mm. Two or three or, more rarely, four, spines arising from

the sicular region; these are 5 or 6 mm. long, and usually at right angles to the axis, but may be slightly concavely curved towards the virgella. Thecæ with apertures perpendicular to the axis, of the generic type, eight to ten in 10 mm. The species is well characterised by the large size of the apertural spines of the earliest thecæ, the long virgella and free virgula. These must have had a wide lumen and thin wall, as they are broadly flattened and do not preserve the usual cylindrical form.

The species is allied to *C. cælatus*, Lapw., but is much larger, and the apertural spines are more strongly developed, and moreover the thecæ, though agreeing in length, differ in the direction of the slope of the aperture.

Locality:—Stockyard Creek; very common.

Climacograptus tubuliferus, Lapw.

(Procs. Belfast Nat. Field Club, 1876-7, p. 138, pl. VI, fig. 33.)

(Plate XIII, fig. 5, Plate XIV, fig. 4.)

Polypary gradually tapering with slightly curved sides; length, 15 mm.; breadth, 2 mm. Virgula expanding distally into a broad lamina or vesicle, free for about 10 mm. Virgella 3 mm. long. Thecæ nine in 10 mm.

A specimen figured from Tingaringi shows the specific character of the broadening of the free virgula distally, a feature which is not so strongly marked in the Stockyard Flat Creek examples. I was at first inclined to refer the latter doubtfully to *C. caudatus*, Lapw., in spite of the shortness of the virgella, a character in which the specimens from both localities agree (as indeed they do in all other visible points), but, as Lapworth's figures* show the same short virgella in *C. tubuliferus*, I refer our specimens all to that species.

Locality:—Stockyard Creek, rare; Tingaringi, common; Tomingley, common; Currawong, doubtfully present.

Climacograptus, spp. indet.

Indeterminable species of *Climacograptus* are present at Lawson, where they are rare, and at Tomingley, where they are common.

Family *Lasiograptidæ*, Lapworth.

Genus.—GLOSSOGRAPTUS, *Emmons*, 1855.

(Am. Geology, 1855, I, Pt. II, p. 108.)

? *Glossograptus mucronatus*, J. Hall.

(Pal. N.Y., I, 1847, p. 268, pl. 73, fig. 1, *a—c*.)

Some imperfect fragments at Lawson are apparently referable to this species.

* Cat. West. Scott., Foss, 1876, Pl. 2, fig. 49; and *l.c. supra*.

Family *Retiolitidæ*, Lapworth, 1873.

Genus.—CLATHROGRAPTUS, *Lapworth*, 1873.

(Geol. Mag., 1873, p. 559.)

Clathrograptus cf. *geinitzianus*, J. Hall.

(Pal. N.York, 1859, III, p. 518.)

(Plate XIV, fig. 5.)

The specimen from Lawson, which I doubtfully refer to this species, is not well preserved, and in fact can only be seen when held obliquely to the light. One end is covered by a distinct periderm, which is thick enough to hide what is below, while the other merely consists of a broken network with roughly hexagonal meshes in three rows, as figured by James Hall. The periderm covered portion shows the thecæ to have been armed with straight blunt spines. Lapworth has referred Hall's species to *Clathrograptus*.† A free virgula is apparently represented by a short impressed line. Breadth of hydrosome, 3 mm.; length, more than 8 mm.

Locality :—Lawson.

Genus.—RETIOLITES, *Barrande*, 1850.

(Graptolites de Bohême, p. 68.)

Retiolites caudatus, n. sp.

(Plate XIV, fig. 6.)

Hydrosome narrowly ovate, about 22 mm. long, and 6 mm. wide, at about the middle of its length, composed of a branching network. Thecæ, 11 or 12 in 10 mm., slightly curved, and at the proximate end opening in the direction of the virgella, and becoming more gradually erect towards the distal end. At about the middle of the hydrosome they are inclined at about 70°. Virgula and virgella, both stout and projecting in each case for about 15 mm. There are doubtful traces of a periderm.

The strong virgula is remarkable, but is found in *R. fibratus*, Lapw. Lapworth refers his species to the subgenus *Neurograptus*, but I am not aware that the subgenus has been defined. A large virgella is found in some species of *Stomatograptus*, but not apparently in any other species of *Retiolites*.

The presence of the genus *Retiolites* in these beds is of considerable interest. Twenty years ago Lapworth† stated that only one Ordovician member of the genus was known, namely, *R. fibratus*, Lapw. This occurs in the Lower Hartfell Beds of Scotland, and in corresponding beds at Carnlea, in Ireland.‖ I have been

† Procs. Belfast. Nat. Club, 1876-7, p. 136.
† Ann. Mag. Nat. Hist., 1880, VI. (5), p. 189.
‖ Swanston, Proc. Belfast Nat. Field Club, 1876-7, p. 122.

unable to find any other reference to an Ordovician *Retiolites*; in fact, most writers of text-books, except Zittel, say that the genus is confined to the Silurian. Frech, in fact, says that *R. fibratus* occurs in *Mittleres Obersilur.*¶

The genera and subgenera of the Retiolitidæ stand in need of a thorough revision. Most of the points in the morphology of *Retiolites geinitzianus*, Barrande, are well known, but even in this species the presence of a periderm is asserted by some and denied by others, and yet this character is regarded by most authors as a generic character of considerable importance. I am inclined to think that the present species had a very delicate periderm; but though I have numerous examples before me the features are too indistinct for a positive statement to be made.

Locality:—Stockyard Creek; very common.

Genus (?).

(Plate XIV, fig. 7.)

A few fragments of rather a remarkable form are present, which evidently belongs to this group, though it is not referable to any of the described genera. It is represented by a number of slightly diverging threads which branch at long intervals. The interspaces are filled by a network of anastomosing fibres. The specimens are preserved, as are all others from the locality, in a silvery-white talcose mineral, and the figured specimen measures 15 mm. in length and 5 mm. in breadth.

Locality:—Stockyard Creek; rare.

DENDROIDEA, *Nicholson.*

Genus.—DICTYONEMA, *Hall*, 1852.

(Pal. N. York, II, p. 174.)

An indistinct specimen from Tomingley may be referred with doubt to *Dictyonema.* The branches are very fine, and cross threads are doubtfully present.

The genus seems rare in Australia, the only specimens hitherto recorded coming from the much older beds at Lancefield, in Victoria.

Genus.—CALLOGRAPTUS, *J. Hall*, 1865.

(Graptolites Quebec Group, p. 133.)

Callograptus cf. *Salteri*, J. Hall.

(Graptolites Quebec Group, 1865, p. 135, pl. xix, figs. 5–8.)

A specimen from Tomingley may perhaps belong to Hall's species, as interpreted by Hopkinson,* and shown in his figures.

* Quart. Journ. Geol. Soc., XXXI, 1875, p. 667, pl. 6, fig. 10.
¶ Lethæa geognostica, 1897, I, p. 669.

Genus Dendrograptus, *J. Hall*, 1865.

Graptolites Quebec Group, 1865, p. 126.

Dendrograptus, spp.

Several species of *Dendrograptus* occur at Tomingley, but are too imperfect for recognition or description in a satisfactory manner.

DISTRIBUTION of the Graptolites hitherto recognised in New South Wales.

	Stockyard Creek.	Currowang.	Tingaringi.	Lawson.	Orange.	Tomingley.	Manduramа.
GRAPTOLOIDEA.							
Family LEPTOGRAPTIDÆ :—							
? Leptograptus	...	...	?	...	...	...	...
? Genus	v.r.	...	...	?	...	...	...
Family DICRANOGRAPTIDÆ :—							
Dicellograptus affinis, n. sp.	v.c.	?	?	...	...	...	...
,, cf. divaricatus, J. Hall	v.r.	...	...	...	...	...	...
,, cf. elegans	...	...	...	...	...	r.	...
,, spp. incert.	...	c.	...	c.	...	...	...
Dicranograptus zic-zac var minimus, Lapw.	...	?	...	r.	...	...	...
Family DIPLOGRAPTIDÆ.—							
Diplograptus Carnei, n. sp.	v.c.	...	...	...	c.	c.	...
,, foliaceus, Murch.	v.c.	c.	c.	...	...	?	...
,, manduramæ, T. S. Hall	...	...	...	...	...	...	c.
,, cf. Whitfieldi, J. Hall	...	...	...	...	...	r.	...
,, spp. incert.	...	...	...	...	...	v.c.	..
Climacograptus affinis, T. S. Hall	...	...	...	...	...	...	c.
,, bicornis, J. Hall	v.c.	r.	v.r.	...	...	...	...
,, hastata, n. sp.	v.c.	...	...	...	...	...	...
,, tubuliferus, Lapw.	r.	?	c.	...	...	c.	...
,, spp. incert.	...	...	...	r.	...	c.	r.
Family LASIOGRAPTIDÆ :—							
Glossograptus cf. mucronatus, J. Hall	...	...	...	r.	...	...	...
Family RETIOTILIDÆ :—							
Clathrograptus cf. geinitzianus, J Hall	...	...	...	v.r.	...	...	...
Retiolites caudatus, n. sp.	v.c.	...	...	...	...	...	...
? Genus et sp.	r.	...	...	...	...	...	...
DENDROIDEA :—							
? Dictyonema	[illegible]	[illegible]	...	[illegible]	...	v.r.	...
Callograptus cf. Salteri	...	...	...	[illegible]	...	v.r.	...
Dendrograptus, spp.	...	[illegible]	...	[illegible]	[illegible]	c.	...

AGE OF THE FAUNA.

TAKING the list as it now stands, the fauna is a homogeneous one; Mandurama, with its scanty record, being the only locality of which we cannot speak with some definiteness. The fauna of this locality I have dealt with elsewhere,* but on the graptolite evidence alone cannot decide on its age, whether Ordovician or Silurian. The other six localities are Upper Ordovician, and stratigraphical evidence will be necessary to establish their sequence. Much larger collections will be required before we shall know whether the zones of the Northern Hemisphere will apply in our Upper Ordovician here. They do not apply in the Lower Ordovician so that we are not justified in assuming a similarity in the case of the younger beds. There is nothing in the present list of known species to cast any real doubt on it, but on the other hand the number of European species is so small that generalisation would be unsafe.

XI.—Notes on Fossil Leaves from the Tertiary Deposits of Wingello and Bungonia: by HENRY DEANE, M.A., M.I.C.E., F.L.S., &c.

(Plates XV, XVI, XVII.)

Pt. I.—Leaves from Wingello.

I HAVE carefully examined the specimens handed over to me, and I give the results below. The collection is only a small one, and it is very desirable that search be made for more examples, as it is impossible to correctly judge the character of the vegetation of the period without a much larger series. A few only appear to be identical with those described by Baron von Ettingshausen in his "Contributions to the Tertiary Flora of Australia"; but it is not improbable that further finds will show a considerable similarity in the fossil flora of the Wingello district to those dealt with in the aforesaid work.

The identification of plants from leaves only is, except in a few cases, very unsatisfactory. I venture to differ altogether from many of the late Baron's identifications, and especially those of which he makes use for the purpose of proving the former existence of a Cosmopolitan Flora. In the following determinations I have adopted the far safer rule, when naming specimens not previously described, of relying on resemblances to examples of the existing flora of the East Coast of Australia where they exist, rather than to forms found only on the

* Rec. Geol. Surv. N.S. Wales, 1900, VII, pt. 1, p. 16

opposite side of the globe and on the other side of the equator. Many of the instances in which Baron von Ettingshausen flew to exotic genera in his search for affinities would be satisfied by comparison with the existing vegetation, and do not therefore by any means support the Cosmopolitan Tertiary Flora theory. As an example of this, his *Quercus Dampieri*, plate IX, fig. 15, is almost an exact copy of a pinna of a leaf of the living *Nephelium leiocarpum*, F. v. M., in my possession. The natural order *Sapindaceæ* to which this plant belongs is largely represented in Eastern Australia. There are twenty-five species in New South Wales alone, without including *Dodonæa*, according to Baron von Mueller's last census, and there are nearly double that number in Queensland. It is not likely that this distribution was effected under present conditions, as most of the species frequent the richer lands and river flats of the coast, which only exist in isolated patches, and we must look back to some earlier age when moister conditions favoured an extension of this forest flora over intermediate parts and over the tableland. It would therefore be natural to expect a considerable development of the natural order *Sapindaceæ* in the more extended ancient forests.

The following species have been found and figured. In addition to these *Lomatia Brownii*, Ett., is also present.

PSYCHOTRIPHYLLUM, gen. nov.

The characters of the leaves adopted for this genus are those of the species of the existing genus *Psychotria*, L., indigenous in Eastern Australia, and especially of the species *P. loniceroides*, Pieb., and *P. daphnoides*, Cunn.

Psychotriphyllum attenuatum, sp. nov.

(Pl. XV, fig. 2.)

Two specimens representing two sides of the same leaf, not unlike the leaf from Vegetable Creek described as *Ficus Gidleyi* in the "Contributions to the Tertiary Flora of Australia," and figured in plate X of that work, but the secondary veins do not curve round and unite in the same way so as to give the appearance almost of an intramarginal vein. The leaf is tapered and the margins are undoubtedly smooth. It is very much like *Elæocarpus*, except that the margins are not serrulate. I consider that the character of the venation corresponds with that of the living *Psychotria loniceroides*, Lieb. (Rubiaceæ), but the leaf is much narrower than in that species, and in shape more like *P. daphnoides*, Cunn.

NEPHELITES, gen. nov.

The characters of the leaves of this genus are somewhat varied, as are those of the living genus *Nephelium*, L., from the resemblance to which the name has been given. The leaves of *Nephelium*, as also of the allied genus *Cupania*, are

pinnate, and it is the detached pinnæ only of *Nephelites* which are most likely to be preserved, but their lopsided or oblique base is a pretty safe indication of their being pinnæ, and not unifoliate leaves.

Nephelites equidentata, sp. nov.

(Plate XV, fig. 3.)

This specimen is not unlike Ettingshausen's *Quercus Dampieri* above referred to, but the teeth are too regular. It seems to me, however, closely allied. I have mentioned above that *Q. Dampieri*, Ett. resembles *Nephelium leiocarpum*, F.v.M. The leaf is lopsided, and might well be the pinnæ of some large compound leaf. An examination of the specimen under review proves that the leaf is not symmetrical. It will be observed that the veins on the left side are much more strongly curved than on the right. The leaf has a well-marked and smooth mid-rib and secondary veins, the latter running out to the points of the teeth; the tertiary venation is indistinct. There seems, however, to be a trace of fine veins running across between the secondary veins, with a fine reticulation between. It has quite the character of some species of *Nephelium*.

Nephelites ovata, sp. nov.

(Plate XVII, fig. 3.)

Leaf or leaflet with smooth margins, lopsided, and most probably therefore one of the pinnæ of a large leaf. It has a strong resemblance to some of the Australian *Sapindaceæ*, and may well belong to that natural order.

FAGUS, *Town.*

Fagus Pittmani, sp. nov.

(Pl XVI., fig. 4.)

This leaf shows the lateral or secondary veins starting from the mid-rib at a very acute angle and then spreading. It is broadly ovate in outline; the margins are not well preserved, but what indication there is tends to show that they were denticulate. The basal vein on the right-hand side shows a well-marked branch towards the margin, and further on there is an indication of a second. These branches of the basal vein occur sometimes in *Fagus sylvatica*, L., although generally they are not present in that species. I think there can be no objection to including this leaf under the genus *Fagus*. It closely resembles *Fagus Benthami*, Ett. (Tert. Fl. Aust., pl. X, fig. 9), but differs from it in shape quite sufficiently to allow of its being considered specifically distinct. In accordance with Ettingshausen's practice of naming his principal species of *Fagus* after distinguished authorities in Australian geology and botany, I have named this one after the present Government Geologist.

Fagus Benthami, *Ett.*

(Tert. Flora Austr., p. 119, pl. X, fig. 9.)

(Pl. XVII, fig. 5.)

This leaf resembles in many respects the one described above, *F. Pittmani*, but it will be seen that it is much more elongated in shape. It is not unlike *Ulmus tasmanica*, R. M. Johnston, but the venation is less marked and more like that of a beech. A certain resemblance to *Fagus Wilkinsoni*, Ett., is also apparent, but the lateral veins are closer together and the margin of the leaf is quite of a different character, On the whole it seems to me to approach nearest to *F. Benthami*, Ett., and I have therefore provisionally included it under that species.

ARGOPHYLLITES, gen. nov.

I have so named this genus on account of its resemblance to the living genus *Argophyllum*, Forst., of Queensland and New Caledonia. The characters are, therefore, those of that genus. One might almost imagine that the fossil leaves possessed the same delicate venation and silvery sheen for which the genus *Argophyllum* is distinguished.

Argophyllites levis, sp. nov.

(Plate XVII, fig. 2.)

A well-preserved fragment of a lanceolate-toothed leaf, probably about 6 inches long. The venation resembles that of existing species of *Argophyllum*, the teeth are very acute and like those occurring in *Lomatia Fraseri*. Judging from the smoothness of the leaf and its general character it might well be related to *Argophyllum*.

CORCHORITES, gen. nov.

Venation generally like that of the genus *Corchorus* (Nat. Order Tiliaceæ). Leaf, rhomboidal in form, margin crenulated, lateral or secondary veins running out to the margin or nearly so, the pair nearest the base much longer and overlapping the next two or three pairs.

Corchorites crenulata, sp. nov.

(Plate XVII, Fig. 1.)

A leaf with a resemblance in its venation generally to *Corchorus Cunninghamii*, F.v.M. The basal pair of lateral veins are well marked; these overlap the veins adjacent to them, while the lateral veins, situated nearer the apex, extend to the margin of the leaf. The tertiary system is well marked, and consists of veins running at right angles or nearly so to the secondary veins. The margins are crenulated, and the apex is less acute than in *Corchorus Cunninghamii*. The same arrangement of venation is found in other genera of the Natural Order *Tiliaceæ*.

CEDRELOPHYLLUM, gen. nov.

Venation generally that of the pinnæ of *Cedrela australis*, or approaching to it.

Cedrelophyllum antiqua, sp. nov.

(Plate XV, Fig. 1.)

Leaflet of a plant probably belonging to the *Meliaceæ*. It is lopsided, and the margins are entire. It has such a close resemblance to a leaflet of *Cedrela Australis*, F.v.M., that I have been much tempted to include it in that living genus, but in general, as elsewhere explained, I do not consider it safe to make use of the name of a genus of living plants.

ALNITES, gen. nov.

This genus is intended to include those leaves the characters of which approach nearly to those of the genus *Alnus*, Gaertn. Fruct. The leaves of the latter genus are mostly oval, somewhat obovate, sometimes slightly cordate at the base, and flattened at the apex. The margins are plainly serrate or sinuate with small serrations following the outline of the sinuations and teeth. The venation is well marked and generally regular, the lateral veins straight, running out to the margin, the upper ones branching at a more acute angle to the midrib than the lower ones. The tertiary veins are, as a rule, well marked, though fine. In the example of *Alnites* described below these veins are inconspicuous.

At the present day the genus *Alnus* has representatives over the greater part of the surface of the earth, but is absent from Australia and the Polynesian Islands. It extends, however, in South America to the Southern Andes, and thus is not unlikely to have reached Australia in former times by the antarctic land connection which is now generally believed to have existed.

Alnites latifolia, sp. nov.

(Plate XV, fig. 4.)

There is a striking resemblance in the venation as represented by the midrib and the lateral veins to *Weinmannia Biagiana*, F. v. M. The tertiary veins are inconspicuous, although there is an indication that they also correspond with the arrangement in that species. The angle at which the lateral or secondary veins leave the midrib becomes smaller towards the apex, and this character again reminds one of *W. Biagiana*. A close examination of the margin, however, which fortunately has been in two places preserved, indicates a different type altogether. It is sinuate-toothed, with denticulations in the sinuses. The general shape of the leaf appears to be ovate, or nearly orbicular. The type of venation

is approached by some of orbicular-leaved species of *Vitis*, by *Grewia* (Nat. Order Tiliaceæ), *Seringia*, *Rulingia*, *Commerconia* (Nat. Order Sterculiaceæ), and some others, while similar marginal outlines as shown in the fossil also exist in the same genera and orders, so that it would require no effort to imagine a leaf which, combining some of the characters of different species or genera of one or other natural order, would fairly resemble the specimen. It is in many respects in shape and venation very like the leaves of *Alnus rubra;* it is more convenient, therefore, to place it under the genus *Alnites*.

LITSÆOPHYLLUM, gen. nov.

Characters of the leaves of *Litsæa dealbata*, Nees. There is no character which does not present itself in one or more species of the genus *Cinnamomum*, but I hesitate to include the leaf in question under *Cinnamomum* for the very reason that that class of venation is not exclusively found in the species of that genus, but in that of others as well, such as *Cryptocarya*. In naming the genus as above, one avoids the necessity of dogmatically asserting that the plant remains necessarily belong to the *Laurineæ*, although the probability that their affinities are to that natural order is very great.

(Plate XVII, fig. 4.)

Litsæophyllum wingellense, sp. nov.

A leaf of the *Cinnamomum* type. Three genera of *Laurineæ* living in New South Wales included species presenting the so-called *Cinnamomum* venation, viz., *Cinnamomum*, *Cryptocarya*, and *Litsæa*. No argument as to the former existence of a cosmopolitan flora can therefore be drawn from the occurrence of the type in fossil leaves. The fossil leaf in question shows a considerable resemblance to *Cinnamomum Burmanni*, a Queensland species, but presents a far greater similarity to *Litsæa dealbata*, Nees, which extends south to the Illawarra.

CINNAMOMUM, Burman.

Cinnamomum Leichhardtii, *Ett.*

(Plate XVI, fig. 5.)

(Tert. Flora Aust., Pl. III, fig. 1.)

Some slight differences occur between this leaf and that figured as above, but they are no greater than occur in living plants. The venation is not only that of *Cinnamomum*, but also of *Cryptocarya*. It closely resembles that of *Cryptocarya triplinervis*, R. Br., a New South Wales species.

PODOCARPUS, Heritier.

Podocarpus præcupressiformis, Ett.

(Plate XVI, fig. 6.)

(Tert. Flora Aust., Pl. VIII, figs. 26, 26a, 27a.)

This has all the characters of the species of *Podocarpus* with small lanceolate acute leaves, and resembles the specimen from Vegetable Creek named by Ettingshausen as above.

PART II—*Leaves from Bungonia.*

NEPHELITES, Deane.

Nephelites denticulata, sp. nov.

(Plate XVI, fig. 1.)

There are two specimens, one being the reverse of the other.

The leaf is crumpled up at the lower end, and somewhat crushed. The venation and margin, which is toothed, are clearly defined in places. The secondary veins run out to the extremities of the teeth; they are curved and sometimes forked. The tertiary veins show a tendency to a disposition at right angles to the secondary veins, and there exists a fine reticulation in between. (The close striations on one side of the leaf are marks due to lateral pressure.) The venation and margin of the leaf resemble some species of *Nephelium*, also some *Ampelidæ*, but on the whole I consider the affinity is to *Nephelium*, a genus now possessing many species, and, with *Cupania* and other genera, forming a prominent section in the existing Flora, probably well represented in the Tertiary. The two sides of the specimen are unequal in width, and there is the lopsidedness, so common to the segments of pinnate leaves.

PERSOONIA, Smith.

Persoonia propinqua, sp. nov.

A fragment of a flat leaf, without thickened or incurved margins. The venation is of a type resembling *Persoonia media*, *P. ferruginea*, and *P. cornifolia*, and I think it may provisionally be placed under *Persoonia*. (Plate XVI, fig. 2.)

DRIMYS, Forst.

Drimys levifolia, sp. nov.

A fragment of a leaf of thin texture, resembling *Drimys*, but it is not possible to determine its affinities with any great certainty. Provisionally it might be placed under *Drimys*, which it more nearly resembles in many respects than the leaves of any other plant. (Plate ~~XV~~ XVI, fig. 3.)

XII.—Palæontologia Novæ Cambriæ Meridionalis—Occasional Descriptions of New South Wales Fossils, No. 4: by R. ETHERIDGE, Junior, Curator of the Australian Museum.

(Continued from Vol. V, Pt. 4, p. 175.)

(Plate XVIII.)

1. SPIRIFERA TASMANIENSIS, *Morris.*

(Pl. XVIII, Figs. 1–3.)

THE exquisitely-preserved shell represented in Pl. XVIII, figs. 1–3, is one of the several varieties passed through by this characteristically Australian *Spirifera.* It differs from the Morrisian type by possessing a less quadrangular outline, rounder cardinal extremities, a shorter shell, and more obliquely rounded antero-lateral angles. The umbo of the ventral valve not only overhangs the entire area, but the umbo of the dorsal valve also. The sulcus accommodates three costæ, the central being the more robust. Each flank carries nine costæ, but the ninth, or outermost on each side, is more or less inconspicuous. The dorsal fold is prominent, projects well to the front, and is longitudinally traversed by four costæ, two central corresponding to the single median of the ventral sulcus, and two lateral which barely attain to the umbo, whilst the flanks are ornamented by eight on each side. The junction of the respective costæ of the two valves at the front produces a well marked zig-zag.

The whole of the costæ of both valves are angular and acute, crossed by very numerous sharp and close-set imbricating frills, imparting to the shell a clean-cut and striking appearance.

The cardinal area is only moderately wide, concave, and delicately longitudinally striate in both valves, but in neither extending actually to the terminations of the cardinal extremities; the delthyrium is widely triangular.

Morris figured* no less than three forms of this species. His Pl. XV, fig. 3, may be regarded as the specific type, and fig. 4 of the same plate as the first variety. This shows a tendency to a lengthening of the shell in proportion to its transverse measurement, but the somewhat acute cardinal extremities of the type form are retained. The third variety (Morris, Pl. XVII, fig. 3) is an external impression, in which the cardinal extremities are extended, and the outline gradually narrowed towards the front; there is also a corresponding increase in the number of costæ. The first variety (Morris, Pl. XV, fig. 4) is also rendered noticeable by the bifurcation of the costæ, nearly every primary being accompanied by a secondary costa emanating from it.

* Strzelecki's Phys. Descrip. N.S. Wales, &c., 1845, t. 15, f. 3 and 4, t. 17, f. 3.

The shell now figured may be looked upon as intermediate between Morris' Pl. XV, fig. 4, and Pl. XVII, fig. 3.

Loc. and Horizon.—Tasmania, Permo-Carboniferous.

2. Productus, *sp. ind.*

(Pl. XVIII, Figs. 4 and 5.)

The internal cast of an unusual form (with us) of *Productus* is represented as above. The outline of the shell is that of *P. subquadratus*, Morris,* but the ventral valve, instead of possessing a uniform convexity or a sulcus, exhibits a very narrow and sharp angular fold, resembling that on the corresponding valve of the Devonian *P. prælongus*, Sby.,† but without the blunt spines of some conditions of the latter.

In this cast the outline is longitudinally elongated, the hinge line very short, the ventral valve highly geniculate and arched, and its umbo projecting vertically downwards over the cardinal area. No trace of sculpture is retained.

I figure this specimen simply as a record for future consideration, but I am inclined to look upon it as a malformed *P. subquadratus*. The median acute fold reminds us of the similar projection on the ventral valve of *P. Christiani*, De Koninck,‡ but without its accompanying sulcus. The most pronounced condition of this narrow fold is seen in *P. mesolobus*, Phill.,§ but there are no other characters in common between the latter and the fossil now under consideration.

Loc. and Horizon.—Hartley—Upper Marine Series.

3. Mytilus Bigsbyi, *De Koninck?*

(Pl. XVIII, Figs. 6 and 7.)

A small cast of one valve is figured, on the assumption that it may be a young condition of *Mytilus Bigsbyi*, De Kon.†† This species is one of the lesser known of our Permo-Carboniferous bivalves, the true generic relations of which have yet to be determined. As only one adductor scar is traceable, the shell cannot be referred to *Aphanaia*, and as the outline corresponds well with that of *M. Bigsbyi* I think the identification is probably correct. The surface is certainly abraded about the position of the upper of the two adductor scars, supposing it to be an *Aphanaia*, but from the appearance presented I am led to believe it possessed only one.

Loc. and Horizon.—Hartley—Upper Marine Series.

* Strzelecki, *op. cit.*, p. 284.
† Davidson, Mon. Brit. Dev. Brach., Pt. 2, 1865, p. 102, t. 19, f. 25.
‡ Rech. Anim. Foss., Pt. I. (Mon. Genus Productus et Chonetes), 1847, p. 166, t. 17, f. 3, 3a-e.
§ Davidson, Mon. Brit. Carb. Brach., Pt. 4, 1861, t. 32, f. 1.
†† Foss. Pal. Nouv.-Galles du Sud, Pt. 3, 1877, t. 21, f. 1 and 1a.

4. Conocardium australe, *McCoy*.

(Pl. XVIII, Figs. 8 and 9.)

Two figures of this species are extant, those of McCoy† and Dana,‡ and a description by De Koninck.§ The descriptions of McCoy and Dana agree generally, but the former says the obliquely sub-truncate anterior end is convex, whereas the latter says the "surface a little concave." McCoy, again, remarks that this anterior area is divided into three nearly equal tumid compartments by two impressed furrows from the beak. Dana, on the contrary, remarks that it is only finely striate longitudinally, a fact in which McCoy, further on in his description, coincides.

In the specimen now before me, although only a cast, the anterior end is certainly slightly convex (McCoy), not concave (Dana), longitudinally striate, as both authors say, and divided into three areas by two impressed lines, as described by McCoy. I cannot see that the costæ of the posterior ends exhibit the arrangement said to exist by Dana, "four broad, nine or ten much narrower, and the following again broader," but they accord much better with McCoy's description. In Dana's figure the anterior end of the shell is so remarkably concave that I am almost led to believe that the authors in question dealt with two distinct species, although the fact that both come from practically the same geological horizon is to some extent against this. Be this as it may, the present specimen from its agreement with McCoy's description can only be regarded as *C. australe* proper.

De Koninck casts some doubt on the identity of the fossil examined by him with McCoy's species, but his description, particularly of the anterior end, coincides much better with McCoy's remarks than does Dana's with the latter, and it may, I think, be safely regarded as *C. australe*.

I am inclined to believe from the appearance of this cast that the front or ventral edges of the valves were internally crenulated and interlocking.

The shell I formerly figured from the Permo-Carboniferous of Queensland as *C. australe*,* I now know is not that species; it is separated therefrom by the characters of its anterior end.

Loc. and Horizon.—Hartley, Upper Marine Series.

5. Modiola? hartleyensis, *sp. nov.*

(Pl. XVIII, Figs. 10 and 11.)

It is impossible to arrive at the correct generic relation of this shell in consequence of the imperfect preservation of the hinge characters. There can be no question, however, that it is undescribed as an Australian fossil, and recalls a type commoner in rocks of a much younger age. The specimen is again a cast.

† *Pleurorhynchus*, Ann. Mag. Nat. Hist., 1847, xx, p. 300, t. 16, f. 4.
‡ *Cardium*, Wilkes U. S. Expl. Expdn., Geol. x, 1849, p. 701, t. 18, f. 2.
§ *Loc. cit.*, p. 284.
* Geol. Pal. Q'land, &c., 1892, t. 14, f. 6.

The united valves were modioliform in outline, moderately convex, the hinge line slightly arched, and less than the width of the shell, the posterior ends broad, and the margins regularly rounded throughout, the ventral margins forming feeble sigmoidal curves, the valves increasing in length posteriorly. There are no marked posterior ridges, but the valve surfaces uniformly convex, sloping off gradually to the posterior ends. Each period of the broad laminæ of growth is terminated by an abrupt declivity, and the laminæ are interstriate concentrically. Along the ventral portions of the valves these laminæ are gathered into bundles; and in the present state of the fossil, along the extreme postero-ventral edges, are frilled. The length is one and a quarter inches, width two and three-eighths inches, and the convexity of the united valves seven-eighths.

M.? hartleyensis is of the type of the *M. lithodomoides*, mihi.† from the British Carboniferous, and *M. cordoliana*, De Ryckholt.‡ As regards Australian species, it is much more modioliform than the smaller of McCoy's figures§ of *M. crassissima*, and from *Modiomorpha? mytiliformis*, mihi,‖ it is at once distinguished by the absence of the curved posterior diagonal ridges, and the abrupt character of the sculpture.

Loc. and Horizon.—Hartley, Upper Marine Series.

XIII.—Notes on some large Chonetine Shells from the Carboniferous of New South Wales. By W. S. DUN, Palæontologist.

(Plates XIX and XX.)

SPECIMENS of the large Carboniferous brachiopod figured in this paper have been for some years in the collection of the Mining and Geological Museum, and there has been some doubt as to what genus they should be referred.

Although we have been able to examine ten specimens, these, unfortunately, exhibit only portions of the pedicle valve, the brachial not being represented at all.

The specimens figured in Pl. XIX, fig. 3, and Pl. XX, fig. 5, show that the surface ornamentation consists of a large number of fine striæ, and in Pl. XX, fig. 5, it is seen that there is a slight concentric marking; this on careful examination is found to be due to distortion only. These specimens also show that the shell was relatively thin.

† Geol. Mag., 1875, 2 (2), t. 8, f. 1 and 2.
‡ De Koninck, Faune Calc. Carb. Belgique, Pt. 5, 1885, t. 28, f. 8.
§ Ann. Mag. Nat. Hist., 1847, XX, t. 15, f. 2.
‖ Geol. Pal. Q'land, &c., 1892, t. 14, f. 5, t. 41, f. 4.

In spite of the relative difference in forms, there can be no doubt that these specimens all belong to the same species, and the example from Rouchel Brook (Pl. XX, fig. 1) is a very wide specimen.

There are no signs of spines, either on the striæ or on the margin of the cardinal area of the pedicle valve.

The internal structure of this valve is, owing to compression and distortion, imperfectly seen in most of the specimens, which, as a rule, are internal impressions showing the position of the numerous foramina, vascular markings, and fine ridgings. An internal cast from near Stroud (Pl. XIX, fig. 2, and XX, fig. 3) shows the large striate flabellate diductor scars and the impression left by a short septum; there is a slightly depressed area on either side of this septum which was occupied by the anterior adductor scars. The hinge-teeth are well developed.

In the original of Pl. XX, fig. 1, though the specimen has been much compressed laterally, it is evident that the diductor scars are more widely separated than in the previously mentioned specimen, the adductor area of attachment appearing to be slightly wider.

The specimens figured in Pls. XIX and XX, figs. 2, 3, 5, have the general appearance of *Chonetes*. As to the original of Pl. XX, fig. 1, it was at first thought that it might represent a *Productus* of the *giganteus* type; but in view of the association with, and close resemblance to, the other specimens described, this view has to be abandoned.

On further comparison of these shells with typical *Chonetes*—taken as a whole—they will be seen to differ in (1) the entire absence of spines on the surface and hinge line, and (2) the shortness of the septum, and to have certain characters in common with *Daviesiella*, Waagen,* which has a finely striate surface, no spines, well developed cardinal teeth, "and a second pair of adductor impressions in the ventral valve."

These shells, on the other hand, resemble *Chonetes* and differ from *Daviesiella* in the thinness of the shell and the internal structure of the pedicle valve, which, according to Pl. XIX, fig. 2, has no second adductor scars. As to the value of the possession of a second pair as a generic character, the remarks of Hall and Clarke quoted later are of great interest, and lead to the conclusions that those authors are of opinion that *Daviesiella* is a Productine shell with Chonetine characters.

Waagen in his subdivision of the Chonetiform shells proposed the genus *Daviesiella* for such forms as *Productus llangollensis*, Davidson, and *P. comoides*, Sby., which had been considered as *Chonetes* by several authors. He said, ... "which are characterised by cardinal teeth and a second pair of adductor

* For figures and descriptions of these interesting fossils, see Sowerby, Min. Conchology, 1823, pl. 329; De Koninck, Mon. Gen. Chonetes, 1847, p. 189, t. 19, f. 1; Davidson, Mon. Brit. Carb. Brach., 1861, p. 180, t. 45, f. 1–7; *Ibid., op. cit.*, Suppl., 1862, pp. 275, 277, t. 46, f. 1, t. 55, f. 6–10; Waagen, Mem. Geol. Survey India (Pal. India), Ser. XIII, 1884, I, p. 613; Hall and Clarke, Pal. N. York, 1892, VIII, pt. 1, p. 317.

impressions in the ventral valve. The other characters are like those of *Productus*." These forms were at first referred by Davidson to *Chonetes*, but after further examination he arrived at the conclusion that "all the interior dispositions were those of *Productus*, and this has proved once more that *Chonetes*, *Aulosteges* and *Strophalosia* cannot be considered in any other light than sub-genera or sections of *Productus*, and cannot claim generic value."† Hall and Clarke, in commenting on Waagen's remarks, quoted above, say:—"The two species are large, ponderous shells, having the cardinal area and teeth conspicuously developed, the external surface covered with fine radiating striæ, and devoid of spines. The existence of the secondary muscular scar in the pedicle valve can hardly be regarded as a distinctive feature, since it is also well defined in some other species of *Productus*. The form and size of the shells, the arrangement of the muscular scars, and their dendritic markings, and the structure of the cardinal process, all show the very close relationship of these species to the typical form of *Productus*. It will be difficult to find features of intrinsic importance upon which to justify the separation of these fossils from Productella . . . . ."

Waagen classed *Daviesiella* in his Chonetinæ—a sub-family of the Productidæ—and while there is no doubt that these New South Wales specimens cannot be referred to Waagen's genus or sub-genus, there appears to be but little in general appearance to refer them to the *Productus*-like genera. Under the circumstances, I prefer to consider them as representing a new species of *Chonetes*, of which the new characters are the short septum and the absence of spines along the margin.

Chonetes aspinosa, *sp. nov.*

Characters of pedicle or ventral valve.—Large, well arched, shell relatively thin, even in the umbonal region, beak not overhanging the hinge area, external surface closely striate and falling within De Konnick's class, Comatæ; area well developed, with well marked dethyrium. No spines on surface or boundary of cardinal area. Cardinal teeth well developed and of moderate size; diductor scars large, flabellate, and not very strongly marked; area occupied by adductors small; medium septum short. Width of largest specimen, 140 mm.; of another, 100 mm.; depth, 6 mm.

Localities.—Binge Berry, Rouchel Brook, County Durham (Pl. XX, figs. 4 and 5; Pl. XIX, figs. 1 and 3.) In calcareous mudstone (C. Cullen.) Pl. XX, fig. 5, in blue limestone.

Torryburn, twelve miles from Paterson (Pl. XX, figs. 1 and 2). In drab-coloured mudstone. Rev. W. H. H. Yarrington, M.A.

Six and a half miles from Stroud, on track to Myall (Pl. XIX, fig. 2; XX, fig. 2). In a fine-grained buff sandstone (C. Cullen).

† *Op. cit.*, p. 275.

XIV.—Notes on some Carboniferous Brachiopods from Clarence Town. By W. S. DUN, Palæontologist.

(Plates XXI, XXII, XXIII.)

I. *Introduction.*

THE Brachiopods described and figured in these notes were collected mainly by Mr. C. Cullen, during the Geological Survey of the country around Clarence Town by Messrs. J. B. Jaquet, A.R.S.M., Geological Surveyor, and L. F. Harper, Field Assistant. The fossiliferous rocks, which Mr. Jaquet calls the "Glen William Series,"* are widely distributed, consisting of "sandstones, claystones, limestones conglomerates, tuffs, cherty shales, and intercalated lava beds. The sedimentary rocks are in part marine and in part fresh-water. The great bulk of the rocks consist of coarse-grained tuffaceous sandstones, which do not contain recognisable organic remains; so that one is unable to determine whether they are marine or fresh-water. . . . . Though locally we found beds which form well-marked horizons, yet we did not find these beds persistent throughout the series, or even over considerable areas. As an example, I may refer to the beds along the Glen William Road, near Clarence Town. Here claystones and fine-grained argillaceous sandstones occur, which yield an abundant marine fauna, and are sharply defined from the coarse-grained arenaceous rocks and tuffs with which they are interstratified. These beds can be traced for a distance of rather more than four miles. They terminate near Stony Creek, upon the south, and beyond this point, upon the same horizon, there are sandstones, &c., devoid of fossils, and altogether dissimilar in character. Upon the western slopes of Wallaroo Hill, Parish of Uffington, we found a bed of marine claystone which can be traced for about half a mile, and then abruptly gives place to other rocks. I could cite many instances of a similar character from elsewhere. When we commenced the geological survey, I intended to have distinguished between the beds of claystone, resembling lithologically the great bulk of the Lower Carboniferous (Gympie) rocks and the arkose sandstones, tuffs, &c., which are so characteristic of the Measures under description. I found, however, after I became better acquainted with the rocks in the field, that I had set myself an almost interminable task, and have in consequence only indicated upon the map the more important fossiliferous marine beds.

"The rapid changes of rock along one horizon, and the complex interstratification of marine and fresh-water beds, would seem to indicate that during Upper, Carboniferous times the land must have been alternately rising and falling, while the presence of worm tracks and drift plant remains in the claystones go to show

* The Iron Ore Deposits of N. S. Wales, Mem. Geol. Survey, N. S. Wales, Geol. 2 (4to, Sydney, 1901), pp. 62–73, geological map and sections.

that the marine beds were deposited in shallow water. The important part taken by volcanoes in the formation of many members of the series may perhaps be cited as additional evidence in support of the contention that they were deposited about a shore line."

With regard to previous references to the brachiopod fauna of the Port Stephens District—Davidson wrote* :—"From a glance I have given to collections sent home from Bundaba and Port Stephens in Australia, as well as from Van Diemen's Land, I have already been able to recognise *T. hastata*, *Sp. striata*, *Sp. glabra*, *Sp. lineata*, *Rh. pleurodon*, *Strept. crenistria*, *Orthis michelini*, *Prod. cora*."

From Booral, Count Strzelecki collected *Reticularia crebristria*, Morris.†

Resulting from examinations of the Rev. W. B. Clarke's collections, De Koninck described‡ from this district:—

Productus cora, from Tilleghary.
„ *semireticulatus*, from Glen William and Williams River.
„ *Flemingii*, from Glen William and Buchan.
„ *punctatus*, from Buchan, Karuah and Williams River.
„ *fimbriatus*, from Tilleghary, Karuah and Williams River.
Chonetes papilionacea, from Dungog.
„ *laguessiana*, from between Karuah and Dungog.
Orthotetes crenistria, from Dungog.
Orthis michelini, from Buchan.
Rhynchonella pleurodon, from between Karuah River and Dungog.
Athyris planosulcata, from near Dungog.
Spirifera lineata, from Buchan, between Karuah River and Dungog.
„ *duodecimcostata*, from Stroud.
„ *pinguis*, from Glen William.
„ *triangularis*, from Stroud.
„ *bisulcata*, from Tilleghary.
Syringothyris exsuperans, from Glen William.
Terebratula saccula, from Stroud.
„ *hastata*, from Stroud.

The Tilleghary referred to by De Koninck is situated on a creek running into the southern portion of Port Macquarie; an extension of the Glen William beds occurs there.

Mr. Etheridge records§ :—From "Lindsay's Branch of Larpent's Creek, *Strophalosia* and *Athyris* (like *A. Roysii* or *A. planosulcata*)" associated with mollusca.

* Mon. Brit. Carb. Brach., Pt. 5, 1863, p. 264.
† Phys. Descr. N. S. Wales and V. D. Land, 1845, p. 279, t. 215, f. 2.
‡ Foss. Pal. N. Galles Sud, 1877, pt. 3.
§ Ann. Rept. Dept. Mines N. S. Wales for 1899, p. 239.

II.—*Description of Species.*

LEPTÆNA, *Dalman.*

(K. Sv. Vet. Akad. Handl., 1827 (1828), pp. 93–94; Hall and Clarke, Pal. N. York, 1892, VIII, Pt. 1, p. 276.)

Leptæna rhomboidalis, *var.* analoga, *Phillips.*

(Pl. XXI, figs. 1, 2, 3.)

Conchita rhomboidalis, Wilckens, Nachricht. von selten Verstein., 1769, p. 77, t. 8, f. 43, 44.

Leptæna rhomboidalis, Wilckens, *supra.*

Productus analoga, Phillips, Geol. Yorkshire, 1836, II, p. 215, t. 7, f. 10.

Strophomena rhomboidalis, var. *analoga*, Davidson, Brit. Carb. Brach., No. 4, 1861, p. 119, t. 23, f. 1–13. (For Synonymy.)

Strophomena rhomboidalis, var. *analoga*, Etheridge, Quart. Journ. Geol. Soc., 1872, XXVIII, pp. 331, 333, t. 15, f. 3 and 5 (?), t. 16, f. 7, t. 18, f. 1.

Strophomenes analoga, De Koninck, Foss. Pal. N. Galles Sud, Pt. 3, 1877, p. 208, t. 9, f. 3, t. 11, f. 7.

Strophomena rhomboidalis, var *analoga*, Eth. fil., Cat. Austr. Foss., 1878, p. 60.

" " " Eth. fil., Geol. and Pal. Q'land, 1892, p. 245, t. 12, f. 8, 9, t. 40, f. 6.

Leptæna rhomboidalis, Schuchert. Bull. U. S. Geol. Survey, 1897, No. 87, p. 240. (American Synonymy.)

Strophomena analoga, Diener, Himalayan Foss., Pal. Ind., Ser. xv, I, Pt. 2, 1899, p. 51, t. 2, f. 17.

This very characteristic fossil occurs in considerable numbers in several localities in this district.

Careful comparisons of Australian with European and American specimens have shown no external differences, and as regards internal arrangement (figs. 1 and 2, Pl. XXI) representing impressions of the interior of a brachial valve will be seen to agree most closely, as regards muscle attachment areas, with Hall and Clarke's Pl. VIII, fig. 24, and Davidson's Pl. XXVIII, fig. 10; and the same condition of the pedicle valve (Pl. XXI, fig. 3) is identical with Davidson's Pl. XXVIII, fig. 9, and Hall and Clarke's Pl. VIII, fig. 25.

This fossil is widely distributed throughout New South Wales; and in the Clarence Town District has been collected from—Quarry, on Glen William Road, about a mile and a half from Clarence Town, Parish Uffington, County Durham; Glen William Road, about two and a quarter, two and a half, and three miles from Clarence Town.

As regards the nomenclature of this well-known form, Hall and Clarke say:* "Whether *L. rhomboidalis* shall be allowed to include all the forms from Silurian

* Hall and Clarke, Pal. N. York, VIII, Pt 1, p. 280.

to Carboniferous faunas which have the characters given in the foregoing diagnosis, or whether the numerous specific and varietal names that have been proposed shall be recognised in whole or part, will depend upon one's conception of specific values. At all events the type of internal structure accompanied by the peculiar corrugated and geniculated exterior has proved a very compact and resistant combination—a fact evinced by the mere possibility of a question arising as to the specific identity of the various forms. It is worthy of note that among the American representatives of this type of structure which have been studied, the extreme differentiation of the muscular area as described is even more distinctly exhibited in the forms of the early Carboniferous than in those of the Silurian and Devonian."

The above-mentioned relative differentiation of the muscle area is entirely borne out by a comparison of Australian Silurian specimens of *Leptæna rhomboidalis*, from the Yass and Murrumbidgee River Districts and Victoria, with the Carboniferous type which, for stratigraphical reasons, is generally listed as a variety *analoga*. Schuchert* is of the same opinion as Hall and Clarke; and De Koninck's† suggestion that *Strophomena analoga*, Phillips, is to be considered as a separate species, appears altogether untenable.

Dr. Diener, in the work quoted in the synonymy, says: "This species belongs to a series of forms, which ranging from Silurian into Permo-Carboniferous deposits, are changing so slightly in their shape and sculpture that the majority of Palæontologists are inclined to consider them as variations of one species only."

PRODUCTUS, *Sowerby*, 1812.

(Min. Conch., p. 153; Hall and Clarke, Pal. N. York, VIII, Pt. 1, 1892, p. 321.)

Productus pustulosus, *Phillips.*

(Pl. XXIII, figs. 1, 2, 3, 14.)

Producta pustulosa, Phillips, Geol. Yorkshire, 1836, II, p. 216, t. 7, f. 15.
„ *ovalis*, *Id.*, *Ibid.*, p. 216, t, 8, f. 14.
„ *rugata.*, *Id.*, *Ibid.*, p. 216, t. 7, f. 16.
„ *punctatus*, De Koninck, Descr. Anim. Foss. Terr. Carb. Belg., 1843, t. 12 bis., f. 3.
„ *pustulosus*, De Koninck, Mon. Gen. *Productus*, 1847, p. 118, t. 13, f. 1, t. 16, f. 8, 9.
„ „ Davidson, Brit. Carb. Brach., No. 4, 1861, p. 168, t. 41, f. 1–6, t. 42, f. 1–4.
„ „ Schuchert, Bull. U.S. Geol. Survey, 1897, No. 87, p. 330 (American Synonymy).
„ *rugatus*, G. Sowerby, Darwin's Geol. Obs. Volc. Islands, 1844, p. 158.
„ *pustulosus*, Etheridge, junr., Cat. Austr. Foss., 1878, p. 53.

---

* *Op. cit.*, p. 280.
† *Op. cit.*, pp. 210, 211.

A few specimens of a large *Productus* have been found in the area under consideration, in no case perfect, a semi-decorticated condition only being presented. Under these circumstances it is a matter of difficulty to decide whether they should be classed as *P. pustulosus* or *P. scabriculus*.

Davidson, in his remarks on *P. scabriculus*,* while dealing with the general resemblance of the two species, says:—"In true *P. scabriculus*, the swollen out, alternating, elongated tubercles are connected by a continued ridge, so that the shell has an appearance of being ribbed, while in *P. pustulosus* the tubercles are more often isolated. The interior, however, in the dorsal valve presents a difference in the shape of the median ridge, which extends from under the cardinal process and divides the adductor impressions. In *P. pustulosus* this ridge is simple, while in *P. scabriculus* it is composed of two ridges, which converge and unite at some distance from their origin into a single ridge; and McCoy says,† in connection with *pustulosus*:—'In all these varieties the isolation of the tubercles, instead of their being mere inflations of distinct longitudinal striæ or ridges, distinguishes the species from the true *P. scabriculus*.'"

No trace of any transverse ridging is to be seen in our specimens; the tubercles are decidedly isolated, and though elongated, there is none of the ribbed appearance ascribed to *scabriculus* by all authors. The greater number and delicacy of the tubercles is noteworthy. The most satisfactory evidence—the condition of the internal median ridge—is unfortunately wanting.

The shell is in all parts thin. In the dorsal valve there is a small well-marked acute umbo; the tubercle-pits are small and distinct, and arranged regularly between the fine concentric ridges. The spines are very fine, and are preserved as a fringe in only one specimen. (Pl. XXIII, fig. 3.)

De Koninck described, but did not figure, a single specimen collected by Clarke on the "banks of the Williams River" as *P. scabriculus*. In this case, he says:* "Toute sa surface externe est couverte de côtes longitudinales remarquables par les renflements alternatifs qu' elles éprouvent et qui les transforment en tubercles disposés un peu irrégulierement en quinconce et souvent ornés de petites épines courbes." His description of the Williams River specimen agrees verbally with that of the same form from Bleiberg†. It is of interest to find that the two species occur in this district, though at the same time it should be borne in mind that the

* *Op. cit.*, p. 170.

† Brit. Pal. Foss., 1855, p. 470.

* Pal. N. Galles Sud, p. 196.

† Mon. Foss. Carb. Bleiberg, 1873, pp. 27-29, t. 1, f. 6

determination of so protean a form as *scabriculus* from a single specimen, unless that be well preserved, must be only tentative.

The species has been found at Glen William Road, two and a half and three miles from Clarence Town, and near the School House, in Parish Wallarobba, on the same road, about five miles from Clarence Town.

PRODUCTUS SEMIRETICULATUS, *Martin.*

(Pl. XXIII, figs. 4–9.)

Anomites semireticulatus, Petr. Derb., 1809, t. 32, f. 1, 2, t. 33, f. 4.

Productus semireticulatus, De Koninck, Mon. Productus et Chonetes, 1847, t. 8, f. 1, t. 9, f. 1, t. 10, f. 1.

" " Davidson, Brit. Carb. Brach., No. 4, 1861, p. 149, t. 43, f. 1–11, t. 44, f. 1–4. (For Synonymy.)

" " Davidson, Suppl. Brit. Carb. Brach., 1880, t. 35, f. 1, t. 36, f. 12, 17.

" *antiquatus*, McCoy, Ann. Nat. Hist., 1847, XX, p. 235, Proc. R. Soc., Tas., 1849–51, I, p. 321.

" *semireticulatus*, De Koninck, Foss. Pal. N. Galles Sud, 1877, Pt. 3, p. 188, t. 9, f. 2. (English Trans., p. 143.)

" " Eth. fil.. Cat. Austr. Foss., 1878, p. 53.

" " Eth. fil., Geol. and Pal. Q'land, 1892, p. 255.

" " Schuchert, Bull. U.S. Geol. Survey, 1897, No. 87, p. 33. (For American Synonymy.)

This easily recognised *Productus*, with its characteristic reticulate ornamentation and spinose alar expansion, has been found at almost every locality where marine Carboniferous deposits occur, being very abundant in the Glen William beds.

De Koninck has described the species from the specimens collected by the Rev. W. B. Clarke at Glen William, and it has been found at the following localities in that district:—Ridge, on the left-hand side of road from Clarence Town to Glen William, four and three-quarter miles from Clarence Town, Parish Wallarobba; Wallaroo Hill, Parish Uffington; Glen William Road, between one and two mile posts, Parish Uffington; Glen William Road, two and a quarter, two and a half, three, and three and a half miles from Clarence Town; and from near the School House, on Glen William Road, about five miles from Clarence Town, Parish Wallarobba, County Durham.

STROPHALOSIA, *King*, 1844.

(Ann. Nat. Hist., XIV., p. 313; Hall and Clarke, Pal. N. York, 1892, VIII, Pt. I, p. 314.)

Strophalosia, *sp. ind.*

(Pl. XXI, fig. 14.)

A compressed external cast of a dorsal valve of *Strophalosia* from near the School House, Parish Wallarobba, on the Glen William Road, about five miles from Clarence Town, is the only record of the presence of the genus in these beds. The surface ornamentation, strong concentric markings, and sparse spinose development, separate it from any of the forms hitherto recorded from Australia. *S. Clarkei*, Eth.,* *Gerardi*, King,† and *Jukesii*, Eth. fil.

ORTHIS, *auctores.*

Schizophoria, *King*, 1850.

(Mon. Perm. Foss. Engl., p. 106; Hall and Clarke, Pal. N. York, 1892, VIII, Pt. I, p. 211.)

Schizophoria resupinata, *Martin.*

(Pl. XXI, figs. 3–9.)

Conchyliolithus anomites resupinata, Martin, Petref. Derb. 1809, t. 49, f. 13, 14.

Orthis resupinata, De Koninck, Descrip. Amin. Foss. Terr. Carb. Belg., 1843, p. 226, t. 13, f. 9, 10.

„ „ Davidson, Brit. Carb. Brach., No. 4, 1861, p. 130, t. 29, f. 1–6, t. 30, f. 1–5. (General Synonymy.)

„ *striatula*, McCoy, Ann. Nat. Hist., 1847, XX, p. 234; Procs. R. Soc., Van Diemen's Ld., 1851, I, p. 320.

„ *resupinata*, De Koninck, Foss. Pal. N. Galles Sud, 1877, Pt. 3, p. 214, t. 10, f. 9; Eng. Trans., p. 166.

„ „ Etheridge, Fil., Cat. Austr. Foss., 1878, p. 49.

„ „ *Id.*, Geol. Pal. Q'land, 1892, p. 244, t. 11, f. 26, 28.

Schizophoria resupinata, Schuchert, Bull. U.S. Geol. Survey, 1897, No. 87, p. 374.

This widely distributed and well marked species occurs in great numbers in the Glen William beds.

Making but slight allowance for local variation, no point can be stated in which the Australian forms differ from the European or American, either in external form or detail of internal structure.

---

* Eth. fil., Geol. and Pal. Q'land, 1892, p. 258, t. 13, f. 12-17, t. 14, f. 19.
† *Ibid.*, p. 260, t. 13, f. 18, t. 14, f. 18, t. 40, f. 7-8.

The Clarence Town specimens differ in point of size from the Queensland forms figured by Etheridge, which are decidedly stunted. The largest individual from Clarence Town examined has a width of 6·5 cm. They are only of moderate depth—a little less than half the width.

As will be seen from the list of localities, this species is both the most abundant and most widely distributed Brachiopod in the area under consideration. It has been found at—Wallaroo Hill and on the Glen William Road at two and a quarter, two and a half, three, three and a half miles from Clarence Town; near the School-house, Parish Wallarobba, about five miles from Clarence Town; and at the foot of Wallaroo Hill, Parish Uffington—about a mile north of the three and a half mile post on the Clarence Town–Seaham Road.

RHIPIDOMELLA, *Oehlert*, 1891.

(Journ. Conchyl., p. 32; Hall and Clarke, Pal. N. York, 1892, VIII, Pt. 1, p. 209.)

Rhipidomella australis, McCoy.

(Pl. XXI, figs. 10, 11.

Orthis australis, McCoy, Ann. Nat. Hist., 1847, XX, p. 234, t. 13, f. 4, 4A.

„ „ Procs. R. Soc. V. Diemen's Ld., 1851, I, p. 320, t. 13, f. 4.

„ *Michelini*, De Koninck, Foss. Pal. N. Galles Sud, 1877, Pt. 3, p. 216, t. 10, f. 10, 10A; Eng. Trans., p. 168.

„ *resupinata*, De Koninck, Foss. Pal. N. Galles Sud, 1877, Pt. 3, p. 214.

„ *Mitchelini*, Etheridge, fil., Cat. Austr. Foss. 1878, p. 49.

„ *resupinata*, Etheridge, fil., *Ibid.*, p. 49.

„ *australis*, Etheridge, fil., Geol. and Pal. Q'land., 1892, p. 245, t. 11, f. 27, 29.

Rhipidomella australis, Etheridge, fil., Contrib. Pal. S. Austr. (in S. Austr. Parl. Paper No. 127), 1897, p. 14, t. 1, f. 2.

This very well marked Orthid was originally described by McCoy in 1847 from specimens collected by the Rev. W. B. Clarke at Lewin's Brook. De Koninck figured specimens, undoubtedly belonging to McCoy's species, as Australian forms of the European *O.* (*Rhipidomella*) *Michelini*, Leveillé, whilst he considered McCoy's figures to represent young specimens of *Orthis resupinata*. Mr. Etheridge, in describing specimens from the Gympie beds (Carboniferous) of Queensland, drew attention to these points, and says:—"Some of these closely resemble *Orthis Michelini*, Leveillé, but differed from this well-known European species in possessing proportionately longer, narrower, and more reniform cardinal muscular impressions . . . . the adductor impressions . . . more heart-shaped and not double as in *Michelini*."

From an examination of well-preserved internal casts of specimens from New South Wales I can quite endorse the separation of *australis* from *Michelini*, and the most casual comparison of our figures (Pl. XXI, figs. 10 and 11) of the internal casts of the dorsal and ventral valves with Davidson's figures of the same condition of *O. Michelini* will at once accentuate the necessity for a separation of the two species.*

The contour and outline and the internal structure of the pedicle valve are undoubtedly that of a *Rhipidomella*, but the disposition of the adductor scars is, as pointed out by Mr. Etheridge, somewhat different from that of *O. Michelini* (the type of the sub-genus). In that group of shells the brachial valve muscle area "is quadruplicate, comparatively small, and usually indistinct." It will be seen that in Pl. XXI, fig. 10, the adductor scars are apparently fused, and it was at first thought that the arrangement differed distinctly from that typical of the sub-genus; and a further examination of other specimens shows that the posterior adductor scar is but faintly separated off from the anterior. To sum up, it may be taken that the brachial valve of *R. Australis* differs from that of *Michelini* in that the posterior adductor scars are not so clearly separated off, and that the general attachment area is more elongate.

It is proposed to deal more fully with the internal structure and relations of this species at a later date.

Specimens have been collected from Wallaroo Hill, Parish Uffington, and on the Glen William Road, two and a quarter, and three miles from Clarence Town.

ORTHOTHETES, *Fischer de Waldheim*, 1830.

(Bull. Soc. Imp. Nat. Moscou, I, p. 375; Hall and Clarke, Pal. N. York, 1892, VIII, Pt. 2, p. 253.)

Orthothetes crenistria, Phillips, sp.

(Pl. XXIII, fig. 11).

Spirifera crenistria, Phillips, Geol. Yorkshire, 1836, II, p. 216, t. 9, f. 6.
Streptorhynchus crenistria, Davidson, Brit. Carb. Brach., No. 3, 1861, p. 124, t. 26, f. 1; t. 27, f. 1–5; t. 30, f. 14–16 (for synonymy).
" " *Id.*, Suppl. Brit. Carb. Brach., 1880, p. 288, t. 37, f. 1–5.
Orthotetes crenistria, DeKoninck, Foss. Pal. N. Galles. Sud, 1877, Pt. 3, p. 212, t. 10, f. 8; Eng. trans., p. 164.
" " Mon. Foss. Carb. Bleiberg, 1873, p. 42 (synonymy).
" " Etheridge, fil., Cat. Austr. Foss., 1878, p. 50.
" " Foord, Geol. Mag., 1890, VII (3), p. 154.
" " Schuchert, Bull. U.S. Geol. Survey, 1897, No. 87, p. 296.

* Davidson Mon. Carb Brach., t. 30, f. 10, 11

This easily recognised Brachiopod is widely distributed throughout N. S. Wales Carboniferous rocks. The cast of a pedicle valve is figured in Pl. XXIII, fig. 11.

It occurs at the following localities in the Glen William District:—Ridge, left-hand side of road from Clarence Town to Glen William, four and three-quarter miles from Clarence Town, Parish Wallarobba; Wallaroo Hill, Parish Uffington; Glen William Road, about two and a quarter to three miles from Clarence Town.

DIELASMA, *King*, 1859.

(Procs. Dublin Univ. Bot. Zool. Assoc., I, p. 260; Hall & Clarke, Pal. N. York, 1894, VIII, Pt. 2, p. 293.)

Dielasma sacculum, Martin, var. hastata, Sowerby (?).

(Pl. XXI, f. 13.)

Terebratula hastata, J. de C. Sowerby, 1824, Min. Conch., t. 446, f. 2, 3.

Conchyliolithus anomites (*sacculus*) Martin, Petref. Derb., 1809, t. 46, f. 1, 2.

Terebratula sacculus, Sowerby, Min. Conch., 1824, t. 446, f. 1.

„ *hastata*, Davidson, Brit. Carb. Brach., No. 1, 1858—p. 11, t. 1, f. 1–12, t. 49, f. 11–30.

„ *sacculus*, var. *hastata*, *Ibid.*, p. 213, 266.

Dielasma hastata, *Ibid.* Suppl., p. 269.

„ „ Morris in Strzlecki, Phys. Descr. N. S. Wales, 1845, p. 279.

Atrypa buindata, McCoy, Ann. Nat. Hist., 1847, p. 231, t. 13, f. 9; Procs. R. Soc. V. D. Land, 1851, I, p. 318, t. 13, f. 9.

Terebratula sacculus, var. *hastata*, De Koninck, Foss. Pal. N. Galles Sud, 1877, Pt. 3, p. 257, t. 15, f. 3. Eng. trans., p. 200.

„ „ „ Etheridge, fil., Cat. Austr. Foss., 1878, p. 61.

„ „ „ Etheridge, fil., Geol. and Pal. Queensland, 1892, p. 226.

Dielasma sacculus, DeKoninck, Faune Calc. Carb. Belg., 1887, Pt. 6, p. 27, t. 6, f. 14–17, 19–26, 35–45, t. 7, f. 60–77.

„ *hastatum* Waagen, Salt Range Fossils (Pal. Indica, Ser. XIII), I, 1882, pp. 337–340.

„ „ Diener, Himalayan Fossils (Pal. Indica, Ser. XV), 1899, I, Pt. 2, p. 80, t. 7, f. 5.

One specimen referable to this widespread and protean species is contained in this collection. This is seen only in section, and is somewhat distorted.

It was collected at Wallaroo Hill, Parish of Uffington.

DIELASMA, *sp. ind.*

(Pl. XXI, fig. 12.)

Associated with the previously described species is an internal cast of a *Dielasma*, characterised by the possession of a markedly ribbed surface. In the brachial valve the presence of a well developed septum is clear, and the nature of the pedicle valve is that of the genus.

It is unfortunate that no perfect specimens of this apparently undescribed species can be examined, but comparison may be made with *Dielasma radiatum*, De Koninck,* which is, however, a much narrower shell.

It is of course possible that the shell may more correctly be placed in *Dielasmina*,* *Notothyris*,† or *Hemiptychina*,‡ of Waagen, but only examination of a large series could decide this point.

RHYNCHONELLA, *Fischer de Waldheim*, 1809.

(Not. Foss. Gouv. Moscou, p. 35; Hall and Clarke, Pal. N. York, 1893, VIII, Pt. 2, p. 177.)

Pugnax, *Hall and Clarke.*

(Pal. N. York, 1893, VIII, Pt. 2, p. 202.)

Rhynchonella (Pugnax) pleurodon, *Phillips.*

(Pl. XXIII, Figs. 10, 11.)

Terebratula pleurodon, Phillips, Geol. Yorkshire, 1836, II, p. 222, t. 12, f. 25–30.

Rhynchonella pleurodon, Davidson, Mon. Carb. Brach., No. 3, 1861, p. 101, t. 23, f. 1–15.

" " De Koninck, Faune Calc. Carb. Belg., 1887, VI, p. 51, t. 15, f. 1–23. (For General Synonymy.)

" " De Koninck, Foss. Pal. N. Galles Sud, 1876, p. 95

" " *Ibid.*, Pt. 3, 1877, p. 219, t. 9, f. 4.

" " Etheridge, fil., Cat. Austr. Foss., 1878, p. 54.

" " Etheridge, fil., Geol. and Pal. Q'land, 1892, p. 244, t. 11, f. 23.

" (*Pugnax*) *pleurodon* Schuchert, Bull. U.S. Geol. Survey, 1897, No. 87, p. 362.

Several examples of this cosmopolitan form have been collected from this district, from which it was also recorded by De Koninck.

Specimens have been collected from Wallaroo Hill, Parish Uffington, and from between the one-mile and two-mile posts, and at two and a quarter, two and a half, and three miles from Clarence Town, on the Glen William Road.

* Faune Calc. Carb. Belg., 1887, VI, t. 7, f. 38–40.
* Salt Range Foss., Pal. Indica, Ser. xi., I, 1882, p. 359.
† *Op. cit.*, p. 375.
‡ *Op. cit.*, p. 361.

SPIRIFERA STRIATA, *Sowerby.*

(Pl. XXII, Figs. 6, 7, 8, 9.)

Anomites striatus, Martin, Petref. Derb., 1809, t. 23.

Terebratula striata, Sowerby, Trans. Linn. Soc., 1815, XII, p. 515, t. 28, f. 1, 2.

Spirifer striatus, Sowerby, Min. Conch., 1820, t. 270.

„ *attenuatus*, Sowerby, Min. Conch., 1825, V, p. 151, t. 493, f. 3, 4, 5,

„ *striata*, Davidson, Brit. Carb. Brach., No. 1, 1858, p. 19, t. 2, f. 12–14, t. 3, f. 2–6.

„ „ *Id.*, Carb. Suppl., 1880, p. 274, t. 31, f. 1, 2, 3, 4, f. 4.

„ *mosquensis*, *Id.*, *Ibid.*, II, p. 22, t. 4, f. 13, 14; *S. striata, var. mosquensis*, Suppl. Carb, IV, p. 274, t. 32, f. 1.

„ „ Waagen, Salt Range Foss., Prod. Limestone (Pal. Indica, Ser. xiii.), I, p. 509, t. 44, f. 3–5.

„ *striatus*, Schuchert, Bull. U.S. Geol. Survey, 1897, No. 87, p. 405. (American Synonymy.)

„ „ De Koninck, Faune Calc. Carb. Belgique, Pt. 6, 1887, p. 112, t. 23, f. 1, 2, t. 27, f. 4.

„ *attenuata*, McCoy, Ann. Nat. Hist., 1847, XX, p. 233; Proc. R. Soc. Van Diemen's Ld., I, p. 319.

„ *striata*, Etheridge, Quart. Journ. Geol. Soc., 1872, XXVIII, p. 334, t. 17, f. 5.

„ „ Etheridge, fil., Geol. and Pal. Q'land, 1892, p. 227, t. 9, f. 16 and ? *S. sp. ind. a. Ibid.*, p. 228, t. 9, f. 12.

„ „ Scupin, Spiriferen Deutschland, 1900, p. 114, t. 9, f. 5; t. 10, f. 1, 3.

It is a matter of great difficulty to separate *Spirifers* of the *striata* type from *S. bisulcata*; but I think that there can be little doubt that the Clarence Town specimens figured belong to the first mentioned.

De Koninck figured and described*, as *S. bisulcata*, several specimens from both Carboniferous and Permo-Carboniferous localities in N. S. Wales; but his figures are not quite convincing, especially Fig. 5c, which has a very *striata*-like appearance. A very marked general character which distinguishes *S. bisculata* from *S. striata* is the presence in the former of three distinct ribs or groups of ribs on the mesial fold, with rare exceptions (*fide* Davidson, *op. cit.*, p. 21).

The Clarence Town specimens are preserved as internal casts, and consequently the condition of the ribbing does not show out very clearly. The mesial fold is

* Foss. Pal. N. Galles Sud, 1877, Pt. 3, p. 246, t. 14, f. 5.

broad, and carries from ten to twelve ribs, which are not bunched into three bundles as in typical *S. bisulcata*. There are from twenty to twenty-two ribs on either side of the mesial furrow.

Traces of lamellar growth lines are preserved in some of the casts, similar to those in *S. musakheylensis*, Davidson, a variety of which, from the Gascoyne River, W.A., has been described by Dr. Foord †. The ribs in the Clarence Town specimens of *S. striata* are not so numerous, nor are they bunched into bundles of seven or eight—a strong character of that species‡.

Specimens have been collected from the following localities in this district:—Glen William Road, one and a half, two and a quarter, three, and three and a half miles from Clarence Town.

SPIRIFERA PINGUIS, *Sowerby*.

(Pl. XXII, Figs. 1, 2, 5.)

Spirifera pinguis, Sowerby, Min. Conch., 1820, III, p. 125, t. 271.

" " Davidson, Brit. Carb. Brach., No. 2, 1859, p. 50, t. 10, f. 1–12.

" " var. *rotundatus*, Sby. De Koninck, Foss. Pal. N. Galles Sud, 1877, Pt. 3, p. 238, t. 14, f. 2, 2a; Eng. trans., p. 185.

" " Etheridge, fil., Cat. Austr. Foss., 1878, p. 58.

" " *Id.*, Geol. and Pal. Q'land. 1892, p. 233.

" " Scupin, Spiriferen deutschlands, 1900, p. 103, t. 9, f. 6a–d.

This well-marked *Spirifer* has already been recorded from Glen William as *S. pinguis*, var. *rotundatus*. Scupin* separates off the larger forms (referred to by Davidson as a variety of *pinguis*) and classes them under M'Coy's *sub-rotundatus*. I can see no object in departing from Davidson's classification,† and considering *S. pinguis*, *rotundata* and *sub-rotundata* as one species.

The Australian specimens have the characteristic broad mesial furrow, ornamented by delicate ridges on both slopes, as figured by Davidson‡. The shape is very transversely oblong-ovate. In the small form figured there are about nine ribs on either side of the mesial furrow; these are broad and not very elevated, rapidly becoming less marked as they get further from the centre of the valve.

Our specimens do not appear to be so circular in outline as those figured by De Koninck.

---

† Geol. Mag., 1890, vii (3), p. 147, t. 8, f. 12, t. 7, f. 2.
‡ Waagen, Salt Range Foss., I, p. 512, . 45.
* Scupin, *op. cit.*, p. 101, t. 9, f. 1a–d.
† Davidson, *op. cit.*, p. 51–52.
‡ Davidson, *op. cit.*, t. 10, f. 10a, 11b.

Specimens have been collected from Wallaroo Hill, Parish Uffington; and on the Glen William Road, at one and a half, two and a quarter, three and a half, and about five miles from Clarence Town (near the School House, Parish Wallarobba), all in County of Durham.

RETICULARIA, *McCoy*, 1844.

(Carb. Foss. Ireland, p. 142; Waagen, Pal. Indica, Ser. xiii, I, p. 538.)

Reticularia lineata, *Martin.*

(Pl. XXII, figs. 3, 4.)

Conchyliolithus (*Anomites*) *lineata*, Martin, Petref. Derb., 1809, t. 36, f. 3.

Spirifera lineata, Davidson, Mon. Brit. Carb. Brach., No. 2, 1859, pp. 62, 264, t. 13, f. 1–13.

Reticularia lineata, McCoy, Carb. Foss. Ireland, 1844, p. 143.

Spirifer lineata De Koninck, Foss., Pal. N. Galles Sud, 1877, Pt. 3, p. 224, t. 11, f. 9; Eng. Trans., p. 124.

„ „ Etheridge, fil., Cat. Austr. Foss., 1878, p. 57.

Reticularia lineata Foord, Geol. Mag., 1890, VII (3), p. 153.

„ „ Etheridge, fil., Geol. and Pal. Q'land, 1892, p. 285.

„ „ Waagen, Pal. Indica, Ser. xiii, I, 1883, p. 54, t. 42, f. 6–8.

„ „ Diener, Pal. Indica, Ser. xv, 1897, I, Pt. 3, p. 56, t. 9, f. 5–7.

Spirifera (*Reticularia*) *lineata*, Scupin, Spiriferen Deutschlands, 1900, p. 52, t. 4, f. 11A, B, 12, 13.

This form occurs only as internal casts, two of which, of the pedicle valve, are figured. The median septum is well developed. The concentric markings are very evident in some specimens, but fainter in others. The radiate striæ are very close.

The type of Morris' *Reticularia crebristria** as collected from Booral, on the same horizon as the Glen William beds, and I am inclined to follow De Koninck in placing this species as a variety only of *R. lineata.* However, I have not seen any specimen of *Reticularia* from these beds with the external portion of the shell preserved, so am not in a position to discuss the matter more fully at present.

The species has been collected from Wallaroo Hill, Parish Uffington, and on the Glen William Road, two and a quarter and two and a half miles from Clarence Town.

* Strzelecki, Phys. Descr. N.S. Wales, 1845, p. 279, t. 15, f. 2; McCoy, Ann. Mag. Nat. Hist. 1847, XX, p. 232; De Koninck, Foss. Pal. N. Galles Sud, 1877, Pt. 3, p. 225, t. 9, f. 5; Foord, Geol. Mag., 1890, VII (3), p. 153.

SYRINGOTHYRIS, *Winchell.*

(Procs. Acad. Nat. Sci. Philad., 1862, p. 6; Hall and Clarke, Pal. N. York, 1893, VIII, Pt. 2, p. 47.)

Syringothyris exsuperans, *De Koninck*, sp.

(Pl. XXI, fig. 18.)

Spirifera exsuperans, De Koninck, Foss. Pal. N. Galles Sud, 1877, Pt. 3, p. 249, t. 15, f. 1; Eng. Trans., p. 195, t. 15, f. 1.

" " Etheridge fil., Cat. Austr. Foss., 1878, p. 56.

Syringothyris exsuperans, Foord, Geol. Mag., 1890, VII (3), pp. 149, 153.

" " Etheridge fil., Records Geol. Survey N. S. Wales, 1897, V, Pt. 2, p. 43, t. 6.

One specimen of this species, showing the high area and the large triangular fissure, has been collected from the Glen William Road, about three and a half miles from Clarence Town.

SPIRIFERINA, *D'Orbigny*, 1847.

(Comptes rendus, XXV, p. 268; Hall and Clarke, Pal. New York, 1894, VIII, Pt. 2, p. 51.)

Spiriferina cristata, *Schlotheim.*

(Pl. XXI, figs. 15, 16.)

Terebratulites cristatus, Schlotheim, Beitr. Naturges. Verstein., Akad. Wissen, Munchen, 1816, t. 1, f. 3.

Spirifer octoplicata, Sowerby, Min. Conch., 1827, p. 120, t. 562, ff. 2, 3, 4.

Trigonotreta cristata, King, Perm. Foss., 1850, p. 127, t. 8, f. 9–14.

Spiriferina " Davidson, Mon. Perm. Brach., 1858, p. 17, t. 1, f. 37–40.

Spiriferina cristata, var. *octoplicata*, Davidson, Mon. Brit. Carb. Brach., No. 1, 1858, p. 38, t. 7, f. 37–47 (for Synonymy).

" " Hall and Clarke, Pal. N. York, 1893, VIII, Pt. 2, p. 52, t. 41, t. 29, f. 17.

" " Schuchert, Bull. U. S. Geol. Survey, 1897, No. 87, p. 410 (for American Synonomy).

" *octoplicata.* *Ibid.*, p. 411.

" *cristata*, var. *octoplicata*, Waagen, Salt Range Foss., Pal. Indica, Ser. XIII, 1883, p. 499, t. 49, f. 3–7.

" " Diener, Himalayan Foss., I, Pt. 3 (Pal. Indica, Ser. XV), 1897, p. 39, t. 7, ff. 5, 6, 7.

I was in considerable doubt at first whether or not to refer this internal cast to Phillips' *Spiriferina insculpta*,* from the fact of there being only three ribs on either side of the sulcus. These ribs do not, however, appear to be sufficiently prominent and inflated to justify a reference to that species; and, in spite of the relatively small number of ribs, the valve has far more of the *cristata* appearance.

In an internal cast of the pedicle valve, the median septum is seen to be well developed. The perforate nature of the shell is well shown by the very numerous small tubercles on the cast, which do not appear to be arranged in any definite order. The sulcus is well marked, and is bounded by two ribs rather more prominent than the rest. There are three ribs on either side of these sulcal ones, making eight altogether.

With regard to the number of ribs in *S. cristata*, var. *octoplicata*, Davidson says*: "The valves are ornamented by eight to twelve angular ribs;" and of the permian form—*S. cristata*—"from four to fourteen angular ribs, of greater or less width, ornament each valve."† Waagen says‡: "The number of these folds varies between eight and fourteen; and Diener, speaking of the Chitichun specimens belonging to a fauna very closely related to that of the Glen William beds, says the number of "folds varies from eight to ten."

Regarding the nomenclature, it is immaterial whether these Carboniferous forms are to be considered as conspecific with Schlotheim's *cristata*, or as a separate variety, *octoplicata*, as was held by Davidson, Waagen, and Diener, many authors on the other hand considering this distinction in terminology unnecessary. It would be out of place in a note of this character to enter more fully into this question; but, after a careful perusal of the literature quoted in the Synonymy, it appears to us that that the term *octoplicata* is of more value from a stratigraphical than from a palæontological point of view.

Specimens have been collected from the Glen William Road, three miles from Clarence Town.

ATHYRIS, *McCoy*, 1844.

(Carb. Foss. Ireland, pp. 128, 146.)

Sub-genus.—Actinoconchus, McCoy, 1844.

(Carb. Foss. Ireland, p. 149; Hall and Clarke, Pal. N. York, 1894, VIII, Pt. 2, p. 92.)

Athyris (Actinoconchus) planosulcatus, *Phillips, sp.*

(Pl. XXI, fig. 17; Pl. XXII, figs. 12, 14.)

Spinifera planosulcata, Phillips, Geol. Yorkshire, 1836, II, p. 220, t. 10, f. 12.

Actinoconchus paradoxa, McCoy, Synop. Carb. Foss. Ireland, 1844, t. 21, f. 6.

* Davidson, Mon. Carb. Brach., p. 42, t. 7, f. 48-53; *vide* also Mon. Dev. Brach., p. 48, t. 6, f. 16, 17.
* Mon. Carb. Brach., p. 38.
† Mon. Perm. Brach., p. 17.
‡ Salt Range Foss., Productus Limestone, I, p. 500.
§ Himalayan Foss., I, Pt. 3, p. 40.

Athyris paradoxa, McCoy, Brit. Pal. Foss., 1855, p. 436.

„ *planosulcata*, Davidson, Mon. Carb. Brach., No. 2, 1859, p. 80, t. 16, f. 2–13, 15. (For Synonymy.)

„ „ De Koninck, Foss. Pal. N. Galles Sud, 1877, Pt. 3, p. 222, t. 9, f. 6; English trans., p. 172.

„ *Roysii*, Etheridge, fil., Geol. Pal. Q'land, 1892, p. 243, t. 11, f. 15.

„ „ *Id.*, Procs. Linn. Soc. N.S. Wales, 1895, IX (2), p. 529, t. 39, f. 4.

Actinoconchus planosulcatus, De Koninck, Faune Calc. Carb. Belg., 1887, Pt. 6, p. 86, t. 21, f. 16, 32.

„ „ Etheridge fil., Records Geol. Survey N. S. Wales, 1898, V, Pt. 4, p. 177, t. 19, f. 18.

The specimen figured shows the dorsal valve and portion of the ventral, with the foramen, the margin of which is somewhat imperfect. The brachial valve, almost decorticated, shows the slightly developed, elongate posterior adductor scars, and the long delicate median groove. Along the margin are preserved remains of several lamellar layers of adhering fine spines.

The character of these spine fringes and the contour of the shell agree exactly with those figured by Davidson.

The specimen figured was collected at about two and a quarter miles from Clarence Town, on the Glen William Road; it occurs also at Wallaroo Hill, Parish Uppington, and between the one and two mile posts, Glen William Road, and also on the same road two and a half miles from Clarence Town.

XV.—On *Atherstonia australis* and *Ctenolates avus*, two new species of Fossil Fishes from New South Wales. By ARTHUR SMITH WOODWARD, LL.D., F.L.S., of the British Museum.

[Plate XXIV.]

Two fossil fishes from New South Wales, recently forwarded to me by the Government Geologist, are of great interest from a stratigraphical point of view. One was obtained from the neighbourhood of Harrington, the other from the coalfield of the Clarence River. These specimens are very incomplete, but both exhibit sufficiently characteristic parts to leave no doubt as to their zoological affinities. They are therefore worthy of a detailed description.

1. *Atherstonia australis*, sp. nov.

(Plate XXIV, figs. 1, 1a, 1b.)

The first specimen, from Harrington, is preserved in a coarse sandstone with an irregular fracture, and represents a fish originally about 0·3 m. to 0·35 m. in total length. The left side is exposed. The head and tail, however, are wanting, and the trunk is a little deepened by distortion, as shown by the arrangement of the scales at the lower border of the fossil. The maximum depth of the trunk would probably equal about one-third the length from the pectoral arch to the base of the caudal fin.

Beneath the position of the head there is a series of about eleven branchiostegal rays (*br.*), all considerably expanded, but the hindermost the broadest. Above and partly behind these, the right infraclavicle and clavicle are also shown. The nfraclavicle (*i. cl.*) is exposed from within, and is clearly a triangular plate bent along its longest or antero-posterior axis. The clavicle (*cl.*) is also exhibited, chiefly from within; but part of its ascending wing is broken away, displaying the impression of a coarse rugose ornament on its outer face, the rugæ being chiefly disposed in a vertical direction. No postclavicular plates are distinguishable.

The scales are rather thick, and are preserved in regular order, except near the ventral margin, where those of the right side are displaced downwards and partly scattered. Those of the flank are much fractured, and their hinder border is not sufficiently well preserved to determine whether or not it was serrated. Some of the principal flank-scales distinctly show a peg-and-socket articulation; but they do not seem to have been strengthened by a vertical ridge on their inner face. The outer face of all the scales is marked with very delicate horizontal or oblique ridges and furrows, which are not all parallel and continuous, but exhibit more or less irregular intercalations, and sometimes radiate from the antero-superior angle. The ornament is feeblest on the scales of the ventral region and the caudal pedicle. The principal flank-scales (fig. 1a) are about as deep as broad, with slightly produced antero-superior angle and gently sigmoidal upper and lower margin. The abdominal ventral scales (fig. 1b) are at least twice as broad as deep, with very prominent antero-superior angle. Some of them retain a feeble peg-and-socket articulation. On the dorsal border remains of a continuous series of large ovate ridge-scales (*r*) are traceable at least as far back as the origin of the dorsal fin. There is also an enlarged ovate ridge-scale (*x*) displaced at the ventral border in front of the anal fin.

The fins are very imperfectly preserved. The pectorals must have been large, as indicated by remains of their broad, closely articulated rays displaced beneath the head (*pct.*). The pelvic fins are not shown. The position of the dorsal is also uncertain, but it probably arose immediately behind the point where the

comparatively small scales are seen displaced at about the middle of the back. The anal fin (*a*) is fragmentary, but must have been comparatively large and remote. Its broad rays are very closely articulated. The caudal fin probably arose quite at the end of the pedicle preserved.

The presence of an infraclavicle indicates that this fish belongs either to the Crossopterygii or to the Actinopterygian Chondrostei. The characters of the branchiostegal rays determine that it is referable to the latter group. Among Chondrosteans it naturally falls within the family Palæoniscidæ; and here it may best be compared with *Acrolepis* and allied genera, which have equally large fins and similar scales.* It is distinguished from all these genera except *Atherstonia* by its continuous series of enlarged dorsal ridge-scales; and as the imperfect fossil now described exhibits no essential features in which it differs from *Atherstonia*, it must for the present be ascribed to this genus. *Atherstonia* has hitherto been known only from the Karoo Formation of South Africa, where at least three species occur. The Australian form is most closely similar to the commonest and type species, *A. scutata*,† from which it seems to be distinguishable by its feebler scale-ornament and the relatively large size of its enlarged anal scale. It is much larger than either of the other described species, *A. minor* and *A. seeleyi*,‡ and differs from these both in proportions and scale-ornament. It may therefore be named *Atherstonia australis*, and probably indicates that the sandstone from which it was obtained belongs to the Hawkesbury Series. Two genera of fishes, *Cleithrolepis* and *Semionotus*, are already known to be common to the Karoo and Hawkesbury Formations.§

2. *Ctenolates avus*, sp. nov.

(Plate XXIV, fig. 2.)

The small specimen from Nimbin, on the Richmond River, is preserved in counterpart, and one side is shown of the natural size in Plate XXIV, fig. 2. It is the middle portion of a Percoid fish, and the actual bones have been destroyed, the parts of the skeleton being indicated only by impressions. There are traces of twenty-two vertebræ in continuous series, and some are lacking both in front and behind. The centra are not deeper than long, and those of the caudal region seem to have been strengthened by one lateral longitudinal ridge. The moderately stout ribs are supported by large transverse processes, and do not extend to the ventral border. The neural and hæmal spines are evidently fused with their respective arches. Of the paired fins, only the distal extremity of one of the pectorals is preserved on the side figured; but on the counterpart there is also

* See Synopsis of genera of Palæoniscidæ in "Catal. Foss. Fishes Brit. Museum," pt. ii (1891), pp. 428-430.

† A. S. Woodward, "On *Atherstonia*, a New Genus of Palæoniscid Fishes from the Karoo Formation of South Africa," Ann. Mag. Nat. Hist. [6], iv (1889), p 239, pl. xiv.

‡ A. S. Woodward, "Further Notes on Fossil Fishes from the Karoo Formation of South Africa," *ibid*, xii (1893), pp. 395-397, pl. xvii, figs. 2, 3.

§ A. S. Woodward, "The Fossil Fishes of the Hawkesbury Series at Gosford," Mem. Geol. Surv. N.S. Wales No. 4, 1890.

the distal portion of a pelvic fin, showing that the rays of the latter extended backwards slightly further than the former. The dorsal fin is noteworthy for the relatively great extent of its spinous portion, impressions of eight smooth spines being preserved and one or two others being doubtless broken away in front. These spines gradually decrease in length to the last but one, which is shortest, and each is borne by a dagger-shaped support. The last spine doubtless joined the following articulated rays in forming a posterior part of the dorsal fin, separated from the anterior part by a notch. There are three smooth spines in front of the anal fin, the second much larger and stouter than the first, and the third crushed upon the foremost articulated ray; the spines are followed in the fossil by remains of at least ten articulated rays. There are no undoubted impressions of the squamation, though certain reticulated markings might at first sight be supposed to indicate a covering of very small scales.

This fossil is too incomplete for exact determination, but it clearly represents a bony, spiny-finned fish of a type which is unknown in the northern hemisphere in formations earlier than the Upper Cretaceous. Its aspect is that of a highly-developed Percoid; and as it is preserved in a carbonaceous shale specially suggestive of a freshwater deposit, I have consulted my colleague, Mr. Boulenger, as to the possibility of its belonging to one of the Percoid genera still existing in the freshwaters of Australia. On making comparisons, we have decided that, so far as its imperfect state of preservation permits judgment, the fossil cannot be generically distinguished from the existing *Ctenolates*, of which one species is widely distributed in the basins of the Darling and Murray Rivers.* The fossil form differs from *C. ambigures* in having two or three articulated anal fin-rays, and may be provisionally named *C. avus*. In any case, there is not much doubt that the stratum in which this fish was discovered is of late Tertiary date.

XVI.—Description of a New Species of *Productus* from the Carboniferous System of New South Wales: By W. S. DUN, Palæontologist.

[Plate XXV.]

THE specimens described in this note were collected by Mr. Charles Cullen at the "Washtubs," near Barrington, on the Australian Agricultural Company's Estate. As a rule the specimens are casts, but in several instances the original structure of the brachial valve is preserved.

* G. A. Boulenger, "Cat. Perciform Fishes, Brit. Mus.," 2nd ed., 1895, p. 134.

Productus barringtonensis, sp. nov.

The shell is large, almost quadrangular transversely, the hinge line forming the greatest width of the shell. Area of pedicle valve small, umbo not very prominent, and not overhanging the brachial valve. From the internal cast (Pl. XXV, fig. 1) it is seen that the muscle-scars cover the larger portion of the umbonal region. The arrangement and general appearance of the anterior adductor and the diductor scars are somewhat similar to that of *P. costatus*, Sowerby, as figured by Hall and Clarke,* but the space occupied by the attachment of the anterior adductors is narrower, and the sinus separating the two areas is more distinct and much simpler in our form, lacking the expansion and rugosities present in the lower half in *P. costatus*. The nature of the surfaces to which the diductors are attached is very similar in the two forms, with the exception that in *P. barringtonensis* the ridges do not terminate as abruptly as in *costatus*, but gradually disappear.

The vascular markings are well shown.

The hinge border is, towards its extremity, furnished with well-developed spines. The alate expansions, as well as the rest of the inner portion of the predicle valve (excepting the area occupied by the muscle scars), are covered with very numerous small pits, represented in the specimen by prickles. Bordering the free margin of the valve is a strip of much thinner shell, with well-developed vascular markings the pore pits are less scattered, and more developed spines were present within this area.

The internal structure of the pedicle valve appears also to differ in some points from the condition obtaining in *P. semireticulatus*,† and there is no point of specific correlation between it and *P. giganteus*, Martin.‡ There is a greater resemblance to the scars of *P. horridus*, J. de C. Sowerby,§ but the area between the diductor scars occupied by the anterior adductor scars are much more restricted in our species—moreover there are great points of difference in the outward form. The external ornamentation of this valve is similar to that of *P. giganteus*.‖

Coming now to the brachial valve (Pl. XXV, figs. 3, 4, 5), it will be seen that the valve is thick, strongly geniculate, and in contour differs from that of *P. semireticulatus* in being more oval and less alate. The surface is covered thickly with ridges and rugosities, but the concentric markings so characteristic of the umbonal region in that species* are wanting. The arrangement of the anterior and posterior adductor scars (Pl. XXV, f. 5) is similar to that of *P. semireticulatus* as figured by Davidson.† The surface of the cardinal process, with the well-marked lateral lobes, is also of the same type.

* Pal N. York, 1892, I, t. 19, f. 13.
† Davidson, Brit. Carb. Brach., t. 44, f. 4.
‡ Davidson, *op. cit.*, t. 37, f. 1, t. 40, f. 1.
§ Davidson, Perm. Brach., t. 4, f. 20.
‖ Davidson, Carb. Brach, t. 40, f. 4.

P. barringtonensis does not appear to approach to any of the Indian Permo-Carboniferous forms. Amongst American Carboniferous *Producti*, comparisons may be made with *P. prattianus*, Norwood,‡ to which there is considerable external resemblance, but between the two species are the same differences as between our form and *P. semireticulatus*; indeed, *P. prattianus* is considered to be a form of *semireticulatus*.§

It was at first thought that this species was only a local variation of *P. semireticulatus*; but, after a careful examination of numerous specimens of that species from Clarence Town, it was considered that their constant resemblance to specimens of the same species from Europe, and the absence of any transition forms, justify the listing of a new species.

XVII.—Analcite-Basalt, from near Sydney: By GEORGE W. CARD, A.R.S.M., F.G.S., Curator and Mineralogist; J. C. H. MINGAYE, F.I.C., F.C.S., Analyst and Assayer; and H. P. WHITE, F.C.S., Assistant Analyst and Assayer.

(Plate XXVI.)

Introduction and general characteristics.

DURING an examination of the olivine basalts intrusive in the Hawkesbury Series (Triassic) of the Capertee Valley, it became necessary, for purposes of comparison, to refer to the corresponding rocks found in the Sydney District.

The occurrence of a perfectly colourless isotropic substance in the groundmass of several of these rocks was noticed, particularly so in a small specimen labelled "Sayer's Tannery, Canterbury," placed in the collections several years ago. The locality in question is situated about a quarter of a mile west-north-west from Fernhill Station, on the Belmore Line, on the south side of Crinan Street. It is plotted on a map lodged with the Department of Mines, Sydney, by J. B. Henson, in 1892. A long trench-like excavation has been made along the dyke for some distance, skirting the side of a small tannery, for the purpose of obtaining road-metal. The metal has been won, partly by an open excavation, partly by tunnelling, and is said to be of excellent quality. Operations have long since ceased, and it

* De Koninck, Mon. Productus et Choretes, 1847, t. 9, f. 1 c and 1 k; Davidson, *op. cit.*, t. 43, f. 1 b.
† Davidson, *op. cit.*, t. 44, f. 1, 2.
‡ White, Geol. Explor. W of 100th Merid., 1875, IV, Pal., p. 113, t. 7, f. 1 a, b, c.
§ Schuchert, Bull. U.S. Geol. Survey.

would now be rather difficult to obtain perfectly fresh stone, the trench being full of water, but a piece was obtained sufficiently sound to establish the locality with certainty. The dyke here traverses the Wianamatta Stage of the Hawkesbury Series. It is about twelve feet wide, and runs north-west and south-west, in direct line with the Canterbury (Moorfields) dyke, three miles away. In places the walls of the dyke are still visible, but no appreciable alteration is apparent.

The rock is blackish in appearance, and shows phenocrysts of fresh olivine to the naked eye, while felspar, and augite can be seen with a lens. The specific gravity of perfectly fresh peices is 2·994.

Chemical composition.

On boiling the finely powdered rock in dilute (1:40) nitric acid, a solution was obtained that gave a very distinct sodium flame, and reacted for alumina, with traces of lime. Gelatinisation ensued on evaporation. The solution from the acetic acid attack also gave a sodium flame. The solution in strong hydrochloric acid gave much iron, with lime and magnesia.

Microscopic characters.

Under the microscope the rock is seen to be porphyritic, and apparently holocrystalline in structure, consisting of phenocrysts of olivine, set in a hypidiomorphic, apparently holocrystalline base of augite, magnetite, felspar, and a colourless interstitial substance, herein described as analcite. The order of separation appears to have been—iron ores, olivine, augite, felspar, analcite.

Olivine.—Crystals sometimes well-formed, but frequently much corroded. Serpentinisation has taken place along cracks, and sometimes peripherally, and an occasional small pseudomorph of serpentine may be seen; otherwise the mineral is perfectly fresh.

Augite.—In broad laths of a warm violet-brown colour, showing prismoidal or granular cross-sections. Occasionally an individual may approximate to phenocrystal development. It may be enclosed by the felspar and olivine, and may enclose magnetite.

Iron Ores.—Abundant in fair-sized crystals, scattered uniformly through the rock. Magnetite and ilmenite (with leucoxene alteration-products) are present. The particles separated from the finely-crushed rock give titanium reactions by the hydrogen peroxide method, so that the magnetite may be itself titaniferous.

Biotite.—Occasional small pleochroic brown flakes appear to be biotite.

Felspar.—Abundant small tabular and lath-shaped forms, occasionally constituting small phenocrysts. Such optical tests as could be applied indicate a variety of labradorite. Occasionally rod-like inclusions, similar to, or even a

continuation of, those referred to below, occur. There is some indication of incipient attack by the weak acid used in etching. The tabular (010) faces are sometimes zoned.

Analcite.—An interstitial colourless substance, perfectly isotropic, even in sensitive light, is an abundant constituent, sometimes almost amounting to a base. No definite outline, and nothing that could be regarded as cleavage, has been anywhere noticed. The form appears to be in all cases that impressed upon it by the contours of the surrounding minerals. There is an apparent alteration into a dusky brown product, but it is difficult to trace. A large brownish dusty patch in the slide, enclosing felspar, augite, iron ores, and certain aggregates of hair-like particles showing speckled double refraction, may represent altered analcite ; but with this exception, the mineral has not been detected other than as an interstitial constituent. After etching with very dilute nitric acid (1 : 40) for a few minutes the mineral is readily stained, the only other constituent to show any appreciable gelatinisation being the serpentinised portions of the olivine. The refractive index is lower than that of the balsam. Colourless rod-like and straight hair-like inclusions are constantly present. The other constituents of the base may also be enclosed by it.

A photo-micrograph of the rock is given on Plate XXVI (fig. 3).

The Canterbury dyke, Moorfields, some three miles away, is in direct line with the Fernhill, and corresponds with it in width. It has been at one time extensively worked, by means of shafts and tunnels, but the excavations have now collapsed. Under the microscope the resemblance between the two rocks is very close, but in the Moorfields slides the areas corresponding to the analcite are dusty-brown and depolarise feebly, but to a somewhat greater extent than in the specimen just described. This is also the case with a slice from a specimen of the Fernhill rock that had lain on the surface for some years; but isotropic analcite of characteristic appearance is present in all the slides. There would seem to be little doubt that these represent two outcrops of one and the same dyke, and it is much to be regretted that there is not more opportunity of securing fresh material.

In 1894, J. M. Curran described* in detail the well-known basalt forming a small boss at Bondi, near Sydney. It is an olivine variety, containing an isotropic colourless mineral, described as being either cubical or hexagonal, and patches of a similar material, traversed by fine needle-like bodies, are scattered through the base.† An analysis is quoted ‡ giving 7·34 per cent. soda, 0·37 per cent. chlorine and 2·50 per cent. water. From this the conclusion is drawn § that the isotropic mineral is sodalite, but the possibility of analcite being present is suggested.

* Jour. Roy. Soc. N.S.W., xxviii, pp. 217-231. Four plates.
† *Loc. cit.* pp. 227-228.
‡ *Loc. cit.* p. 225.
§ *Loc. cit* p. 225.

The analogy between the isotropic substance in the two rocks was evident, but very careful chemical tests failed to reveal more than a bare trace of chlorine in the Fernhill basalt. The absence of chlorine conclusively proved that the isotropic mineral could not be sodalite, and a re-examination of the Bondi rock seemed desirable. Accordingly, very thorough analyses were made of two samples of Bondi basalt and one of Fernhill rock, together with a partial analysis of a third Bondi specimen. The Bondi specimens were personally obtained, and the samples for analysis carefully broken out from the interior of solid lumps. This latter precaution was considered advisable as the Bondi rock is on the coast, exposed to the spray from the surf. The results agree very closely, the Bondi and Fernhill rocks having an almost identical composition. Beyond a trace (0·031) of soluble Na.Cl., evidently derived from the sea, no chlorine could be detected; moreover the analyses differ in several other most important respects from that quoted by Curran, notably in showing a much lower percentage of soda. It appears as if by some unfortunate error the value of the latter analysis has been quite vitiated. The chemical composition of the Bondi rock is accordingly now re-discussed. There is no necessity to repeat the petrographical account, but it may be mentioned that the micro-slides in the Survey collections do not show the cubical or hexagonal sections of the isotropic mineral mentioned by Curran.*

* *Loc. cit.* p. 227.

RESULTS OF ANALYSES.

	I.	Ia.	II.	III.	IV.	V.	VI.	VII.	VIIa.	VIII.	VIIIa.	IX.	IXa.	X.	Xa.	XI.
SiO_2	41·10	685	41·58	43·39	43·48	.....	724	35·66	594	36·88	614	41·70	695	41·57	693	45·59
Al_2O_3	14 82	145	21·68*	16·67	16·53	.....	162	22·45	220	22·51	220	19·05	187	19·86	195	12·98
Fe_2O_3	2·35	15	10·31	3·47	3·42	.....	21	8·13	.....	9·71	.....	7·64	106‖	9·84	136‖	4·97
FeO	10·38	144		8·80	8·91	.....	123									4·70
MgO	9·43	236	9·03	7·30	7·12	.....	180	4·27	107	5·63	141	3·87	96	5 21	130	8·36
CaO	10·56	188	4·27	8·79	8·88	.....	158	7·65	136	7·32	131	6·93	124	6·45	115	11·09
Na_2O	3·94	63	8·88	3·30	3·27	3·31	52	10·18	164	8·09	130	9·22	149	7·49	121	4·53
K_2O	1·28	14	0·99	2·17	2·31	2·31	24	1·44	15	1·33	14	1·31	14	1·23	13	1·04
H_2O (at 100° C)	0·39	.....	.....	0·29	0·31	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0·51
H_2O (over 100° C)	2·31	128	3·26	2·67	2·69	.....	148	6 32	351	6·22	345	5·73	318	5·76	320	3·40
CO_2	0·26	6	.....	0·39	0·40	.....	9	2·34	53	1·40	32	2·15	49	1·28	29	.....
TiO_2	3·20	40	.....	2·20	2·35	.....	28	.....	.....	.....	.....	.....	.....	.....	.....	1·32
P_2O_5	0·19	.....	.....	0·41	0·44	.....	.....	1·56	11	0·91	6	2·49	17	1·31	9	0·91*
V_2O_5	minute trace.	.....	.....	0·01	0·01	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
SO_3	0·09	.....	.....	0·19	0·21	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Cl	minute trace.	.....	.....	0·02	0·03	0·03	.....	.....	.....	.....	.....	.....	.....	.....	.....	0·05
Cr_2O_3	trace	.....	.....	trace	trace	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
NiO, CoO	trace	.....	.....	trace	trace	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
MnO	0·14	.....	.....	0·19	0·15	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0·14
BaO	0·06	.....	.....	0·02	0·02	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0·13
SrO	trace	.....	.....	trace†	trace†	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0·12
Li_2O	present	.....	.....	present‡	present‡	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	trace
	100·50		100·00	100·28	100·53			100·00		100·00		100·00		100·00		99·87

* ZrO_2—0·08.

I. Analcite–Basalt, Fernhill : complete analysis of the rock.
Ia. ,, ,, : molecular ratios corresponding to analysis I.
II. ,, ,, : analysis of portion soluble in boiling nitric acid (1·40) in two minutes. Calculated to 100. Including the silica soluble in alkali, 37·40 per cent. of the rock is soluble.
III. ,, Bondi : complete analysis of the rock.
IV. ,, ,, : ,, ,, (another sample).
V. ,, ,, : partial ,, (a third sample).
VI. ,, ,, : molecular ratios corresponding to an average of III and IV.
VII. ,, ,, : analysis of portion soluble in cold dilute acetic acid (16·60 per cent.) in two hours. Calculated to 100. (1·72 per cent. of insoluble silica was removed from the residue by soda carbonate.)
VIIa. ,, ,, : molecular ratios corresponding to analysis VII.
VIII. ,, ,, : analysis of portion soluble in boiling dilute nitric acid (1·40)—28·41 per cent. in two minutes.§ (2·28 per cent. of insoluble silica was removed from the residue by soda carbonate.)
VIIIa. ,, ,, : molecular ratios corresponding to analysis VIII.
X. ,, ,, : analysis VII recalculated after adding the 1·72 of silica taken up by soda carbonate.
IXa. ,, ,, : molecular ratio corresponding to analysis IX.
X. ,, ,, : analysis VIII recalculated after adding the 2·28 of silica taken up by soda carbonate.
Xa. ,, ,, : molecular ratios corresponding to analysis X.
XI. ,, The Basin, Colorado : complete analysis of the rock.

* Including P_2O_5, &c. † Less than 0·01 per cent.; presence determined by flame colouration and spectroscope. ‡ Presence determined by spectroscope
§ The silica extracted by nitric acid (1·40) in one hour is practically the same as that taken out in two minutes. ‖ Calculated as FeO.

Analyses I, II, by H. P. White; III, IV, V, VII, VIII, by J. C. H. Mingaye; XI, by W. F. Hillebrand.

Discussion of the Analyses.

The Brögger and Mügge diagrams corresponding to the analysis of the Fernhill rock are given on Plate XXVI. The former (fig. 1) clearly shows the low silica percentage of the rock, the large proportion of alkaline earths and iron oxides, and the predominance of soda over potash. The latter (fig. 2) shows the constitution of the rock, bringing out the fact that there is a slight excess of alumina after satisfying the alkalies. These are the most important general points, together with the high percentage of combined water.

Carbonic anhydride:—The Bondi analyses give nine and the Fernhill six molecules respectively of CO_2. Although the pieces analysed were very sound, there might be a little carbonate of lime present as an alteration-product of the pyroxene; but the uniformity of the results point to the possibility of cancrinite being present, although that mineral has not been detected under the microscope.

Titanic oxide:—The violet pyroxene is undoubtedly a titaniferous variety. Titaniferous iron ores are also present.

Phosphoric anhydride:—Much is removed by the dilute solutions; it may be regarded as combined with lime as apatite.

Sulphuric anhydride:—Two molecules are present in each rock, and may be taken as indicating the presence of nosean.

Chlorine:—As mentioned above, the minute quantity found in the Bondi basalt is combined with sodium in the soluble condition, and must therefore exist as common salt.

Native iron was tested for directly, and found to be practically absent, there being no evolution of hydrogen with sulphuric acid.

The ready gelatinisation and solubility of both rocks in dilute cold acetic acid and in warm very dilute (1·40) nitric demands special attention. By etching an uncovered slice with the dilute nitric acid for a minute or two and staining it is seen that the portions attacked are—

(*a*) the isotropic interstitial matter;

(*b*) the serpentinous alteration-products. Olivine is not attacked.*

The results obtained by treating the Bondi rock with dilute acids (Tables VII to XI) is chosen for elaboration.

Regarding the silica removed from the residues after the acid attack as soluble, a total percentage of 30·69 and 18·32 of the finely powdered rock is soluble respectively in the nitric and acetic acid. Very considerable amounts of lime, magnesia, and iron oxides are taken up; these may be considered as belonging

to the serpentinous decomposition products. A portion of the lime may be combined with carbonic anhydride, and a very minute quantity must be present as phosphate. The iron is mainly in the ferrous condition, and is regarded as such in the molecular ratio columns. The percentage of soluble silica from the Fernhill rock is practically the same as, but the percentages of soda and water are respectively greater and less, than in that from Bondi.*

It will be noticed that the larger portion of the total soda and water have gone into solution, but very much less of the potash. Probably the undissolved potash belongs to the small quantity of biotite present in the rock.

Combining sufficient silica, alumina, and water with the alkalies to satisfy the analcite formula—Na_2O, Al_2O_3, $4SiO_2$, $2H_2O$—a slight excess of silica and alumina is left. Silica, and probably water will be required by the ferro-magnesian products, but there is not sufficient to satisfy the general formula for serpentine; still the ratios obtained do certainly point to some such grouping of the molecules as that shown below.

The following tabular statement may be regarded as representing the molecular constitution of the soluble portion of the Bondi rock :—

Soluble in—

	Cold acetic acid in two hours. Table IXa.					Boiling nitric acid (1 : 40) in two minutes. Table Xa.				
	Total.	Analcite.	Calcite.	Apatite.	Balance.	Total.	Analcite.	Calcite.	Apatite.	Balance.
SiO_2	695	652	...	...	(+) 43	693	536	...	...	(+) 157
Al_2O_3	187	163	...	...	(+) 24	195	134	...	...	(+) 61
FeO	106	...	...	...	(+) 106	136	...	...	...	(+) 136
MgO	96	...	...	...	(+) 96	130	...	...	...	(+) 130
CaO	124	...	49	51	(+) 24	115	...	29	27	(+) 59
Na_2O	149	163	...	..	.....	121	121			
K_2O	14					13	13	...	...	.....
H_2O	318	326	...	...	(−) 8	320	268	...	...	(+) 52
CO_2	49	...	49	...	.....	29	...	29	...	.....
P_2O_5	17	...	...	17	.....	9	...	...	9	.....

The Magmatic Formula of the Fernhill rock is as follows :—

SiO_2	685			6·5 RO 1·6 R_2O_3 6·8 SiO_2
Al_2O_3	145	160		
Fe_2O_3	15			4 RO, R_2O_3, 4·2 SiO_2
FeO	144			
MgO	236	568	645	Molecules of bases to 100 of silica = 117.
CaO	188			
Na_2O	63	77		R_2O : RO = 1 : 7.
K_2O	14			

* Experiments were made which tend to show that pure olivine is readily attacked by very dilute acids, but as the olivine was not stained it may be assumed that it remains intact under the conditions of the test.

* 30·90 per cent. of the total silica was dissolved out by 1·40 (HNO_3) in two minutes, 32·82 in one hour (same acid), and 42·18 by HCl 10 per cent. in twenty minutes; the acid used in each case being boiling.

Evidence for the existence of Analcite.

Nothwithstanding the accumulation of evidence during the last five years that analcite may occur as a primary constituent in igneous rocks, recent editions of the text-books still speak of it as of secondary origin only. As early as 1890 Lindgren described* an analcite-basalt from Highwood Mountains, Montana. This was a fresh rock, consisting of magnetite, olivine, augite and analcite, crystallisation taking place in the order named. In 1896, L. V. Pirrson† discussed the group of rocks known as monchiquites, and summed up the evidence in favour of the existence of primary analcite in certain rocks. His conclusions have been received with almost universal acceptance. He says (1): "The determination of a colourless isotropic substance containing silica, water, soda, and alumina, and which gelatinises with dilute acids in a rock is as safe a determination of analcite as that of the majority of minerals determined in eruptive rocks." Again (2): "The magmas producing these (*i.e.*, the analcite-bearing rocks G.W.C.) have certain chemical characteristics in common, low silica, moderate alumina and alkalies with soda predominating over potash, and high lime, and iron, and high to moderate magnesia."

One of the latest writers on the subject, Dr. J. W. Evans,‡ gives a bibliography, so that further reference to the literature is not necessary here. Dr. Evans considers (page 49) "that analcite is an eutectic compound; that is, it represents a combination of silica, alumina, soda, and water, with a little potash, which solidifies at a lower temperature than any mixture of those substances which differs to any considerable extent in the proportions of its constituents, or in having an admixture of other materials."

The substance described as analcite in these rocks possesses the following characteristics :—

(*a*) isotropism;

(*b*) absence of colour;

(*c*) low index of refraction (less than Canada balsam);

(*d*) extremely ready gelatinisation;

(*e*) it is a hydrous silicate of alumina and soda, closely approximating in molecular constitution to the analcite formula;

(*f*) has separated from the magma later than any other constituent, and is therefore interstitial.

---

* Proc. Calif. Acad. Sci., 1893, Ser. 2, iii pp. 51-57.

† Analcite Group of Igneous Rocks. Journ. Geol., iv p. 679.

(1) Op. cit., p. 685.

(2) Op. cit., p. 688.

‡ Q. J. G. S., 1891, lvii, No. 225, p. 49.

In all these respects the criteria laid down by Pirrson and others are satisfied by these Sydney basalts. It must, however, be admitted that no evidence of cleavage or of certain crystal form can be adduced. Moreover, the proportion of silica, and to some extent water, in the soluble portion is rather low; but the study of the latter is complicated by the presence of iron, lime, and magnesia, derived from alteration-products of uncertain composition. No separation of the substance—with consequent determination of its specific gravity and exact composition—has as yet been satisfactorily made; but a small proportion of the finely-powdered rock floated on methylene iodide of density 2·3.

The absence of crystal form, the perfect isotropism, and the presence of so much water, are against the occurrence of nepheline in any large quantity.

The manner of occurrence of the analcite, and the freshness of the rocks as a whole, quite preclude the possibility of a secondary origin.

Previous writers having shown some uncertainty as to what would be the action of dilute acid upon an acid glass, the experiment was tried of subjecting obsidian from Iceland to boiling nitric acid (1:40). The silica dissolved from five grammes of powdered obsidian was unweighable. It may, therefore, be taken as certain that the isotropic substance cannot be glass.

Conclusion.

Prof. T. W. E. David and Mr. W. G. Woolnough, of the University of Sydney, have called our attention to the presence of analcite in the diabase intrusive in the Hawkesbury Series at Prospect, near Parramatta. Undoubted secondary analcite is present, but the occurrence of the same mineral enclosing apatite crystals completely detached from the surrounding rocks, is considered as pointing to its presence as a primary constituent as well.

It is not without interest to refer to a conclusion drawn by Pirrson on theoretical grounds. He says:* "It would follow that the conditions most favourable to the production of primary analcite rocks would be in dikes and small intrusions . . . . , while surface lavas would appear as . . . . nephelinites, etc." This is exactly the mode of occurrence of these Sydney rocks, and a small patch of nepheline-basalt of Post-Triassic age does actually cap the mountain known as the Peaks, Upper Burragorang, overlying the Hawkesbury Sandstone.

It is anticipated that more of the Post-Triassic basalt dykes and flows will shortly be proved to be analcite-bearing; and it may even be possible to establish a definite petrographical province.

* *Loc. cit*, p. 687.

PLATE IX.

Description of Figures.

1. Diagram graphically illustrating the composition of eclogite from Ruby Hill, Bingera (Brögger Method).

2. Diagram graphically illustrating the composition of eclogite from Ruby Hill, Bingera (Mügge Method). Alumina is seen to be in great excess of that required to satisfy the alkalies. The preponderance of lime is very evident.

3. Diagram graphically illustrating the composition of nepheline-basalt from Sapling Flat, Capertee (Mügge Method). The alumina is insufficient to satisfy the alkalies, the deficiency being indicated by a horizontal stroke, a continuation of the soda radius.

4. Diagram graphically illustrating the composition of nepheline-basalt from Sapling Flat, Capertee (Brögger Method).

In each case the molecular ratios, not the weight percentages, have been utilised, and the totals have not been brought to 100. The scale used is one millimetre to a molecule.

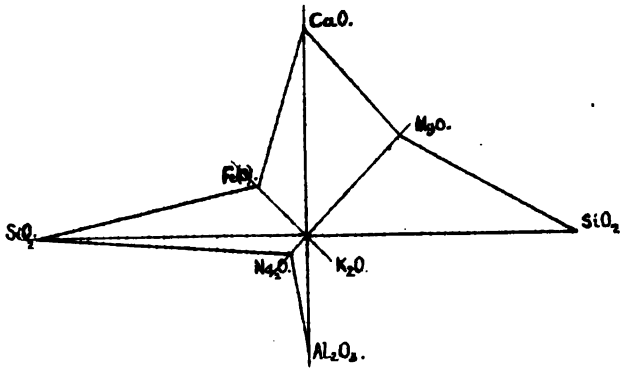


Fig. 1.

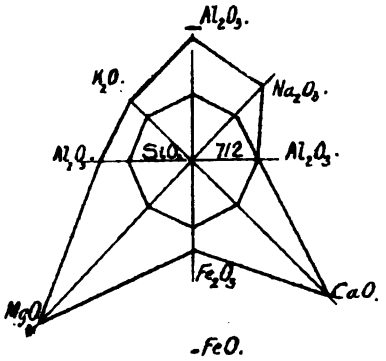


Fig. 3.

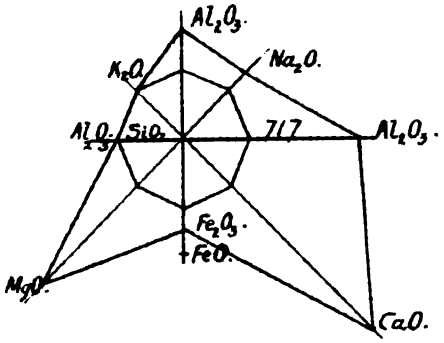


Fig. 2.

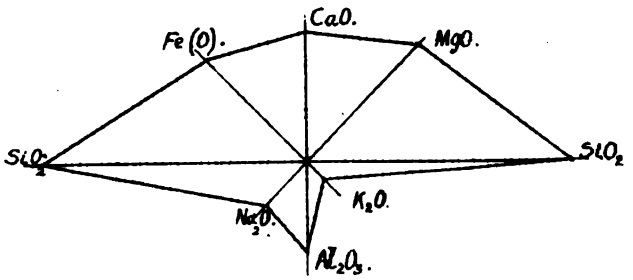


Fig. 4.

Photo-lithographed by
W. A. Gullick, Government Printer,
Sydney, N.S.W.

PLATE X.

Description of photo-micrographs of eclogite from Ruby Hill, Bingera.

Fig. 1. Garnets, altered throughout, and showing a bifurcating tubulated structure. Slide 1929D x 40.

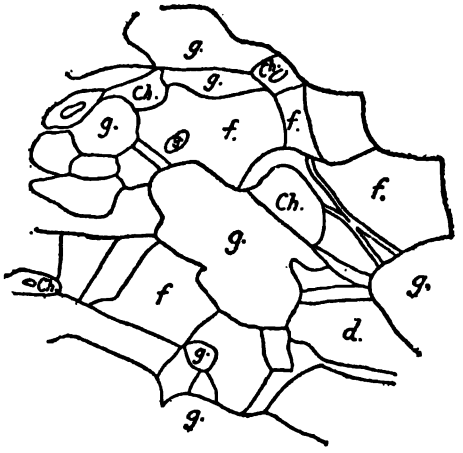
Fig. 2.

Slide 1929A.

c—Cyanite; six-sided section.
d—Diopside; cleaved.
g—Garnet; altered.
f—Felspar.
ch—Chondritic granule.
n—Unaltered nucleus of garnet.

Fig. 3.

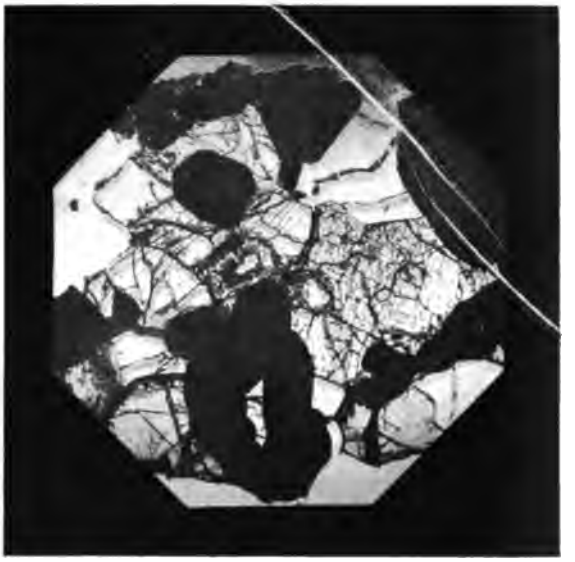
Slide 1929E.



d—Diopside; shattered and intruded by alteration products.
g—Garnet; altered.
f—Felspar; shattered and intruded by alteration products.
ch—Chondritic granules.

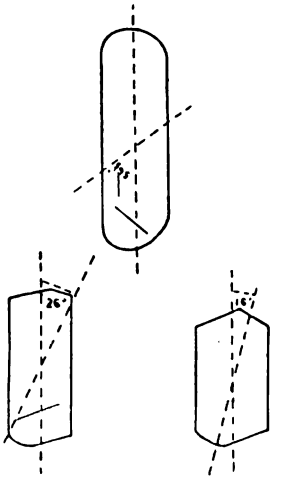
Fig. 4. Cyanite crystals, from the eclogite. Six-sided cross-sections and a longitudinal section with rounded terminations are shown, and also the extinction angles.

1



2

3



4

PLATE XI.

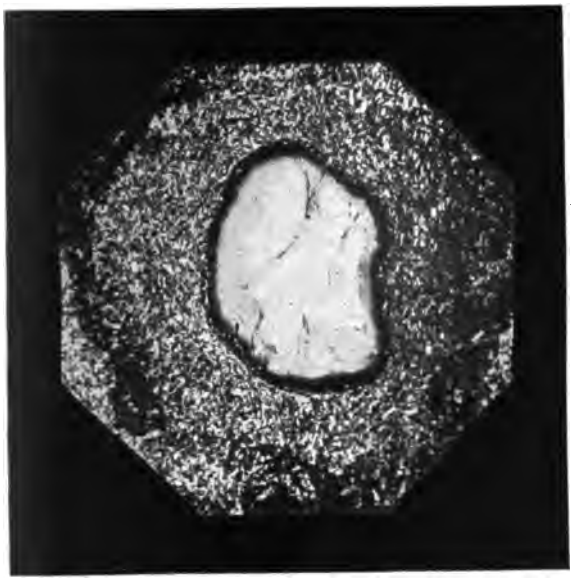
Description of figure illustrating different stages of the alteration of garnet. The examples are all selected from inclusions in the basalt of Ruby Hill, Bingera. 1-in. objective.

Fig. 1. Garnet in basalt, surrounded by a zone of radially fibrous anisotropic material "kelyphite rim." The colour deepens outwardly, becoming finally opaque. Slide 1940B. x 17.

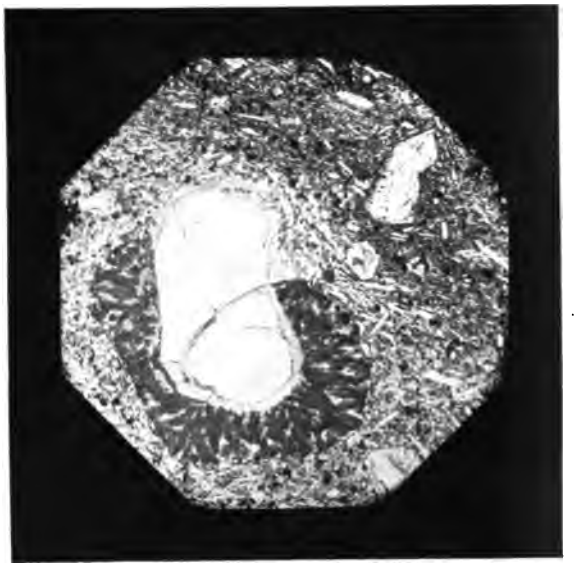
Fig. 2. Garnet, with cleaved diopside, partly enveloped by a zone of dusky matter with radial patches of colourless anisotropic material. Slide 1944. x 40.

Fig. 3. A nucleus of unaltered garnet, surrounded by an inner zone of kelyphite and an outer of dusky material as in Fig. 2. There is a peripheral skin of closely aggregated magnetite granules. Slide 1944. x 40.

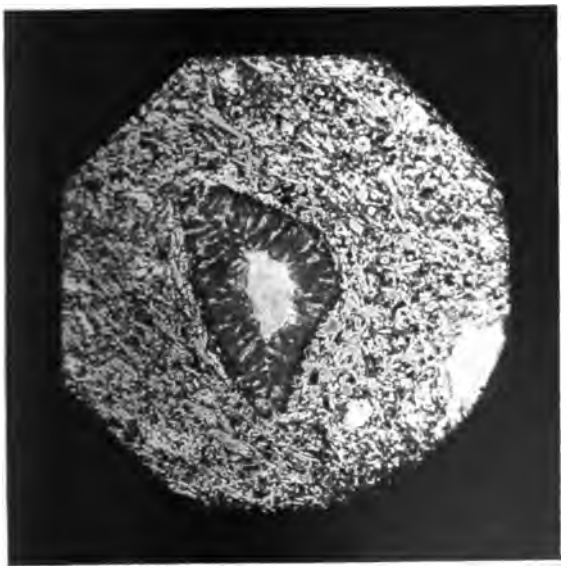
Fig. 4. Completely altered garnet, with a colourless inclusion. The central area is occupied by brown, irregularly-streaked or mottled, feebly doubly-refracting material. The peripheral zone consists of granular magnetite in plumose aggregates set in a colourless antisotropic base, having a low index of refraction. Slide 1943T. x 40.



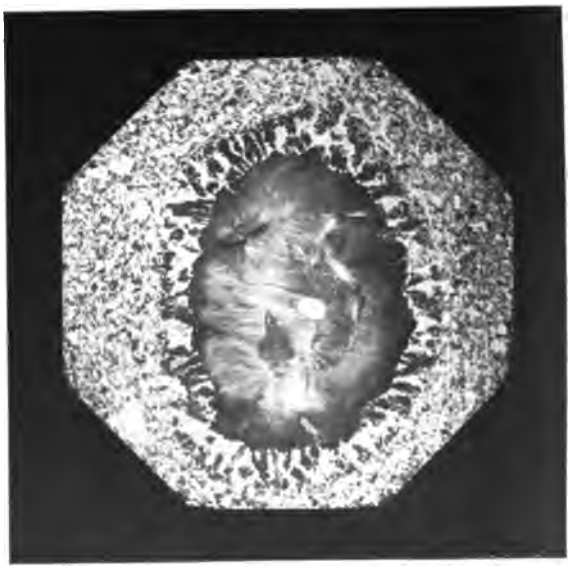
1



2



3



4

Photo-micro. G.W.C.

PLATE XII.

Leptograptidæ, *Pleurograptus* (*?*) sp.

Fig. 1. Fragment from Stockyard Creek.

Dicellograptus affinis, sp. nov.

Fig. 2. Base of specimen figured on Pl. XIII, fig. 2.

Dicellograptus cf. *divaricatus*, J. Hall.

Fig. 3. Base of specimen from Stockyard Creek.

Dicellograptus cf. *elegans*, Carruthers.

Fig. 4. Specimen from Tomingley.

Dicranograptus ziczac, var. *minimus*, Lapworth.

Fig. 5. Specimen from Parish Lawson.

Diplograptus Carnei, n. sp.

Fig. 6. Specimen from Stockyard Creek.

Diplograptus foliaceus, Murch.

Fig. 7. Specimen from Stockyard Creek.

Climacograptus bicornis, J. Hall.

Fig. 8. Var. *longispina*, Stockyard Creek.

Fig. 9. Normal form, Stockyard Creek.

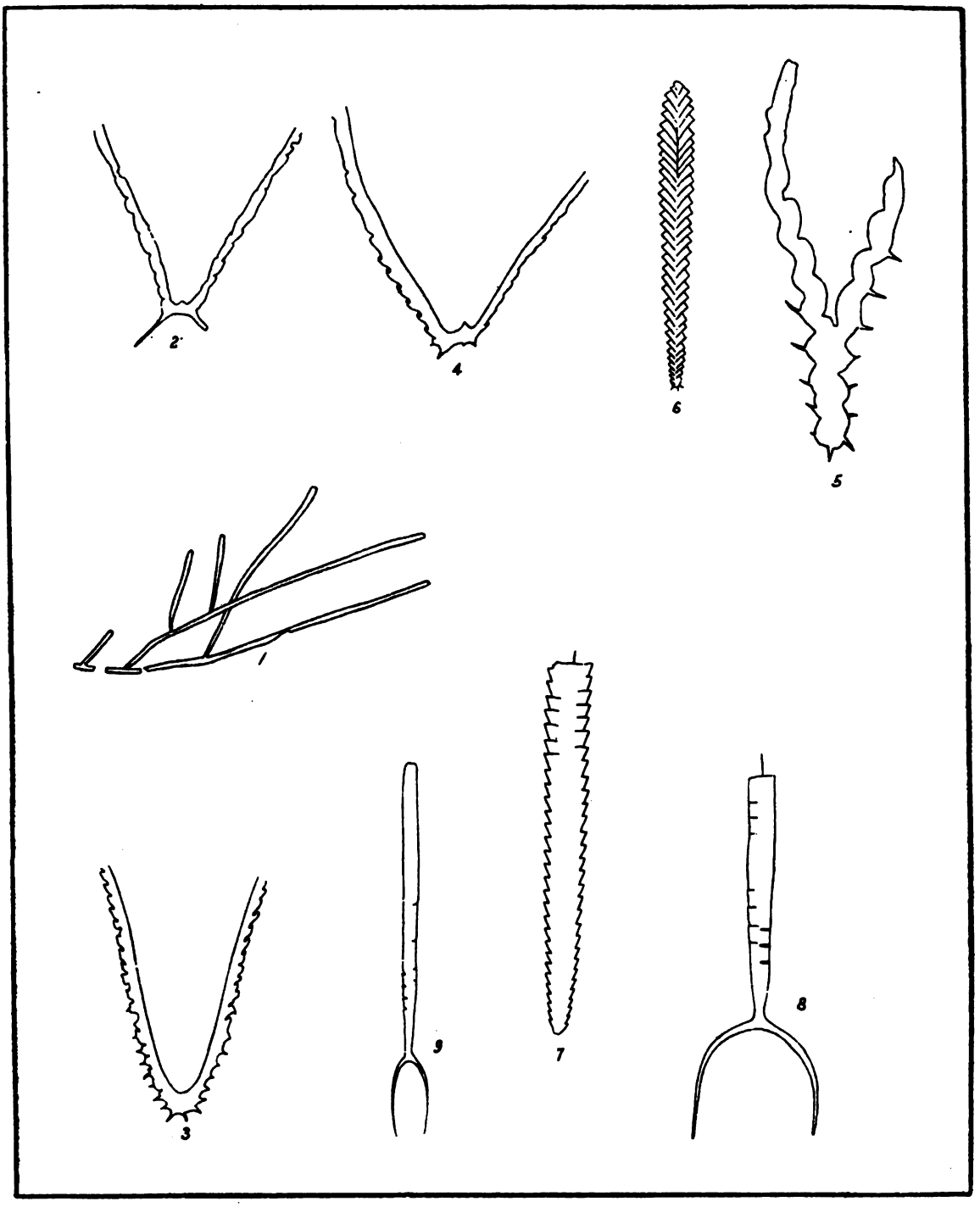


Photo-lithographed by
W. A. Gullick, Government Printer,
Sydney, N.S.W.

PLATE XIII.

Dicellograptus affinis, n. sp.

Fig. 1. Specimen from Stockyard Creek. Nat. size.

Fig. 2. Another specimen, with the branches crossed, enlarged, from Stockyard Creek.

Dicellograptus cf. *divaricatus*, J. Hall.

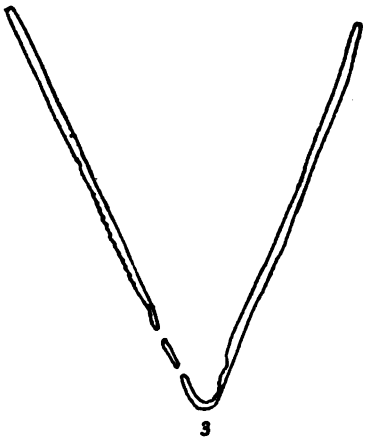
Fig. 3. Specimen from Stockyard Creek. Nat. size.

Dicellograptus or *Dicranograptus*.

Fig. 4. Specimen from Parish Lawson.

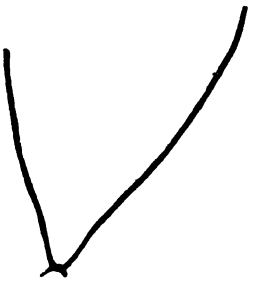
Climacograptus tubuliferus, Lapworth.

Fig. 5. Specimen from Tingaringi. Nat. size. A small fault cuts across the specimen.



3

5



1

2

4

1121

Photo-lithographed by
W. A. Gullick, Government Printer,
Sydney, N.S.W.

PLATE XIV.

Climacograptus hastata, n. sp.

Fig. 1. From Stockyard Creek.

Fig. 2. Base of another specimen, showing two spines.

Fig. 3. Base of another specimen, showing three spines.

Climacograptus tubuliferus, Lapworth.

Fig. 4. A specimen from Stockyard Creek.

Olathrograptus cf. *geinitzianus*, J. Hall.

Fig. 5. Specimen from parish Lawson.

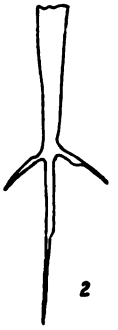
Retiolites caudatus, n. sp.

Fig. 6. Specimen from Stockyard Creek.

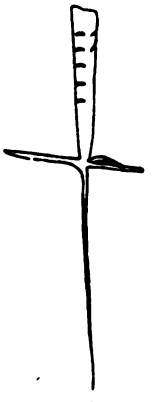
Retiolitidæ—genus (?)

Fig. 7. Specimen from Stockyard Creek.

1



2

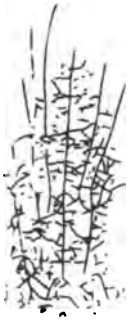


3

4

5

6



7

1121

Photo-lithographed by
W. A. Gullick, Government Printer,
Sydney, N.S.W.

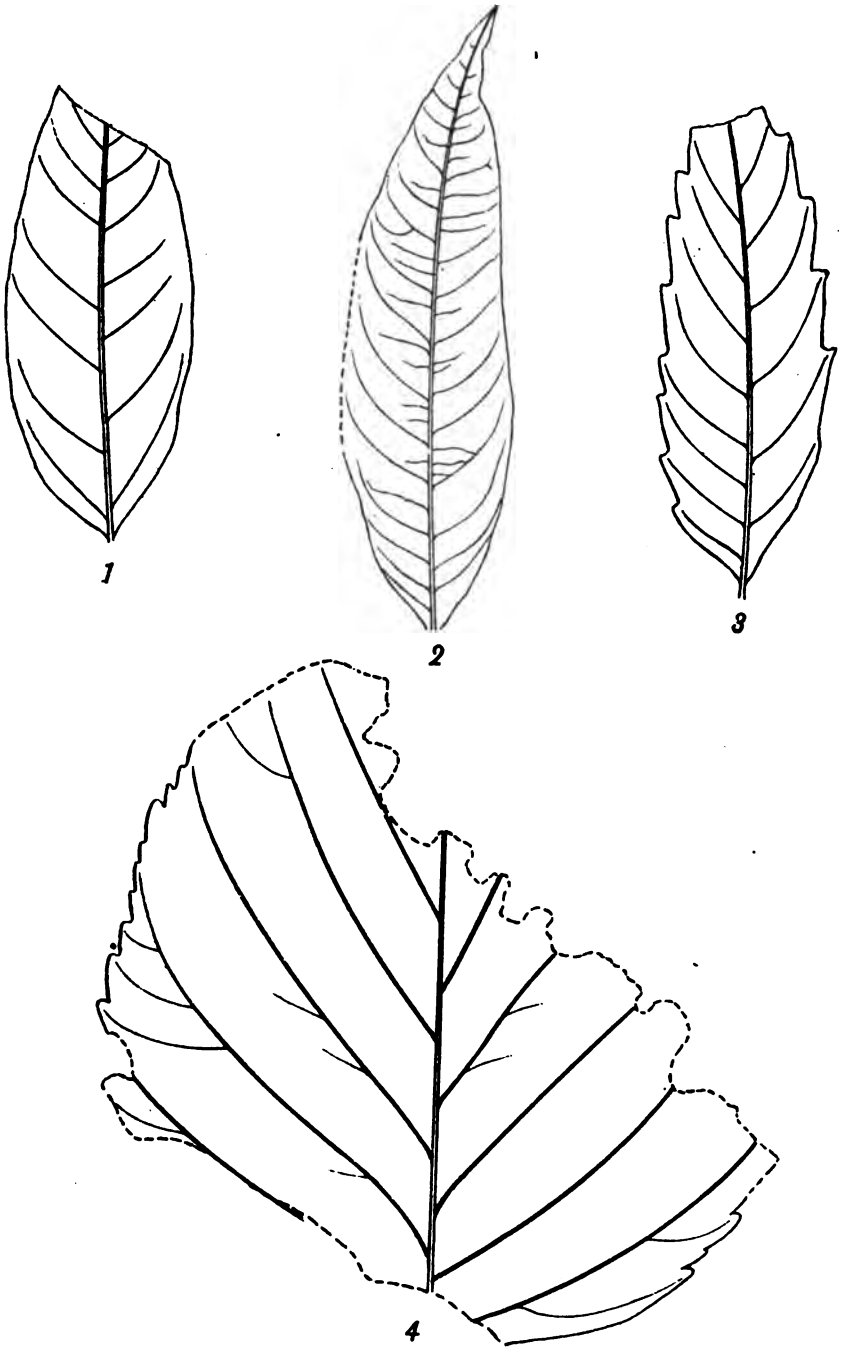
PLATE XV.

Fig. 1. Leaflet of *Cedrelophyllum antiquum*, sp. nov.

Fig. 2. *Psychotriphyllum attenuatum*, sp. nov.

Fig. 3. *Nephelites equidentata*, sp. nov.

Fig. 4. *Alnites latifolia*, sp. nov.



Frank R. Leggatt, del.
79941

Photo-lithographed by
W. A. Gullick, Government Printer,
Sydney, N.S.W.

PLATE XVI.

Fig. 1. *Nephelites denticulata*, sp. nov. From Bungonia.

Fig. 2. *Persoonia propinqua*, sp. nov. From Bungonia.

Fig. 3. *Drimys levifolia*, sp. nov. From Bungonia.

Fig. 4. *Fagus Pittmani*, sp. nov.

Fig. 5. *Cinnamomum Leichhardti*, Ett.

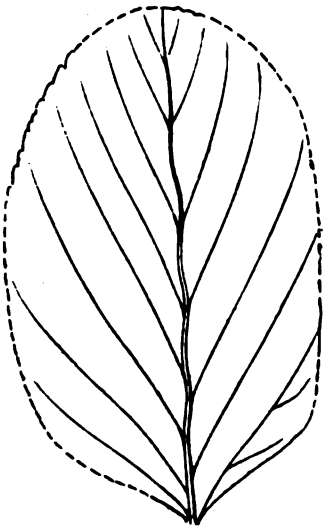
Fig. 6. *Podocarpus præcupressiformis*, Ett.

1

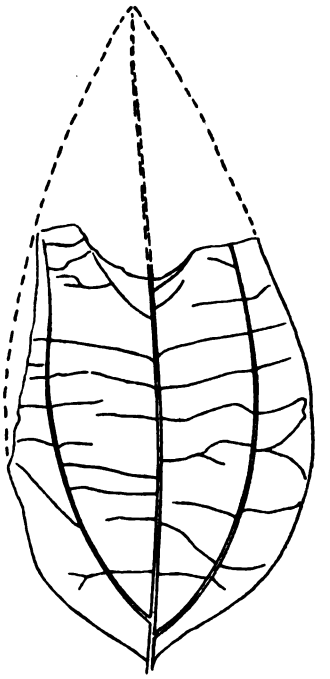
2

3

6



4



5

Frank R. Leggatt, del.
79941

Photo-Lithographed by
W. A. Gullick, Government Printer,
Sydney, N.S.W.

PLATE XVII.

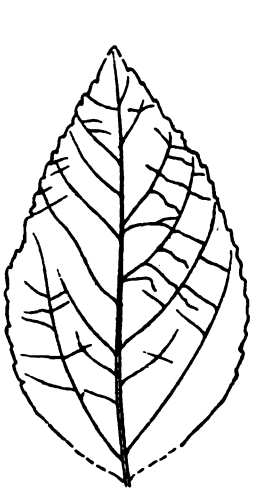
Fig. 1. *Corchorites crenulata*, sp. nov.

Fig. 2. *Argophyllites levis*, sp. nov.

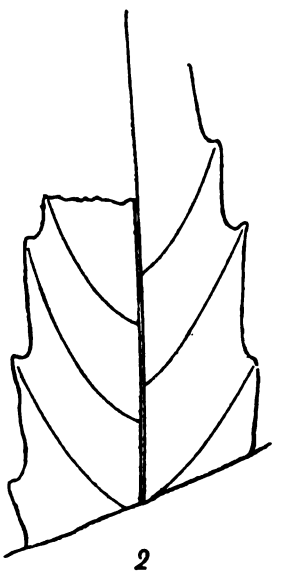
Fig. 3. *Nephelites ovata*, sp. nov.

Fig. 4. *Litsæophyllum wingellense*, sp. nov.

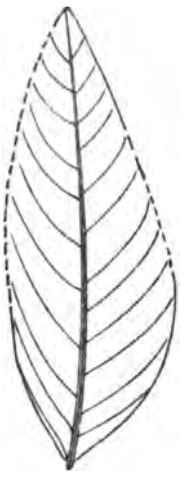
Fig. 5. *Fagus Benthami*, Ett.



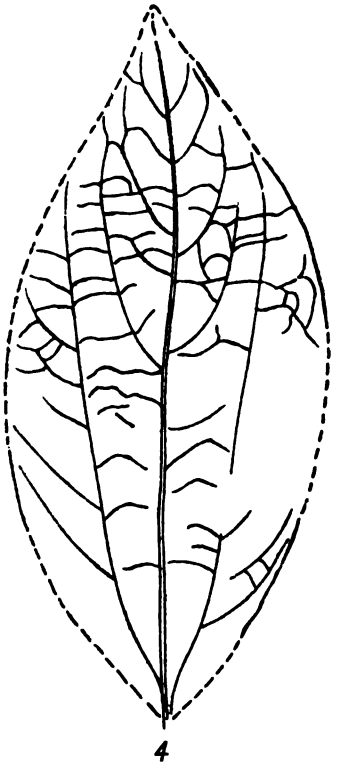
1



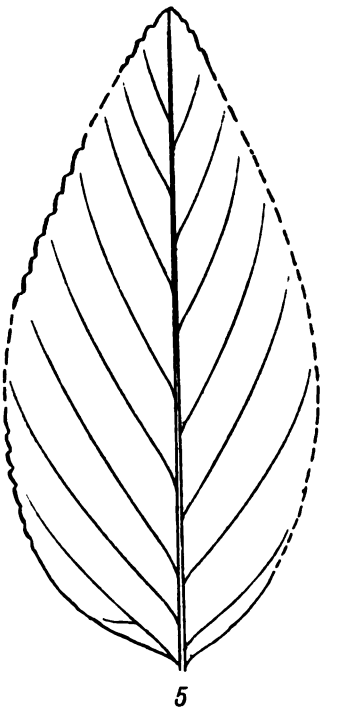
2



3



4



5

Frank R. Leggatt, del.
79941

Photo-lithographed by
W. A. Gullick, Government Printer,
Sydney, N.S.W.

PLATE XVIII.

Spirifera tasmaniensis, Morris.

Fig. 1. The dorsal valve, cardinal area, and umbo of the ventral valve.
Fig. 2. The ventral valve.
Fig. 3. Conjoined valves in apposition.

Productus, sp. ind.

Fig. 4. The ventral valve with the sharp median fold.
Fig. 5. The ventral valve, side view, showing the overhanging umbo.

Mytilus Bigsbyi, De Koninck ?

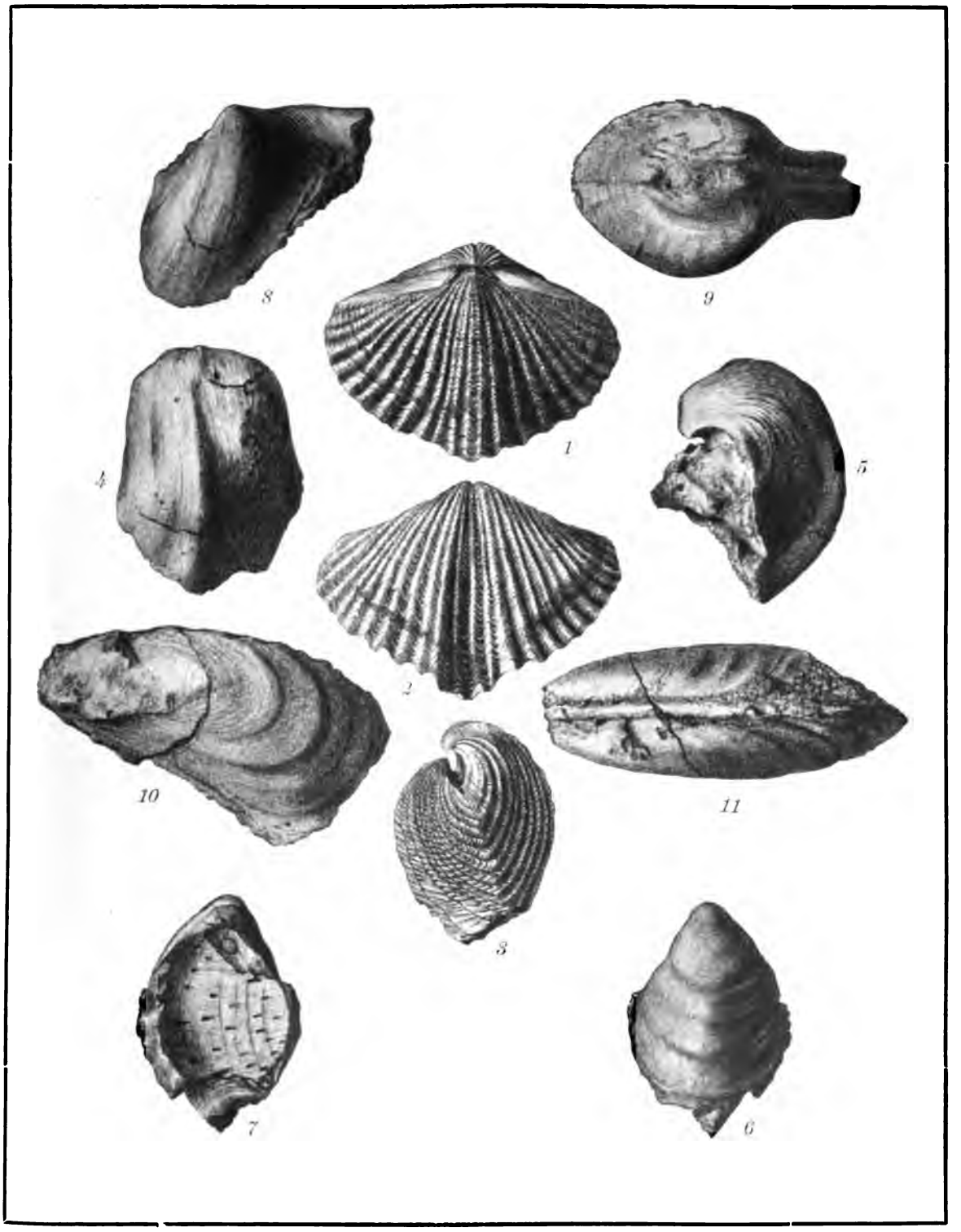
Fig. 6. The left valve, exterior view.
Fig. 7. The left valve, partial view of the hinge, with portion of a *Productus* pressed into the concavity of the valve.

Conocardium australe, McCoy.

Fig. 8. The left valve, imperfect towards the posterior end.
Fig. 9. The conjoined valves in apposition.

Modiola ? hartleyensis, Eth. fil.

Fig. 10. The left valve, with the wide abruptly terminated laminæ of growth.
Fig. 11. The conjoined valves in apposition.



T. P. Hammond, del.

PLATE XIX.

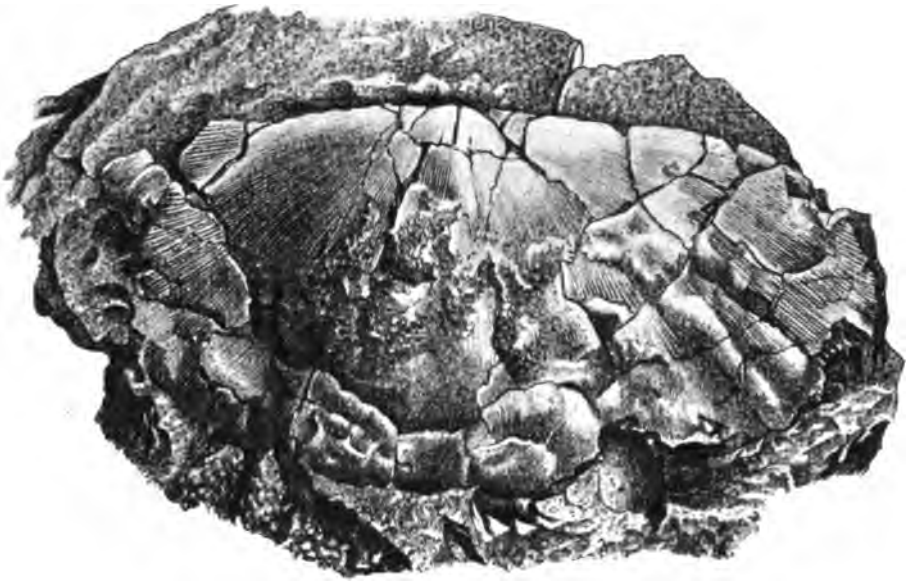
Chonetes aspinosa, sp. nov.

Fig. 1. Shattered compressed specimen of pedicle valve, showing surface ornamentation.

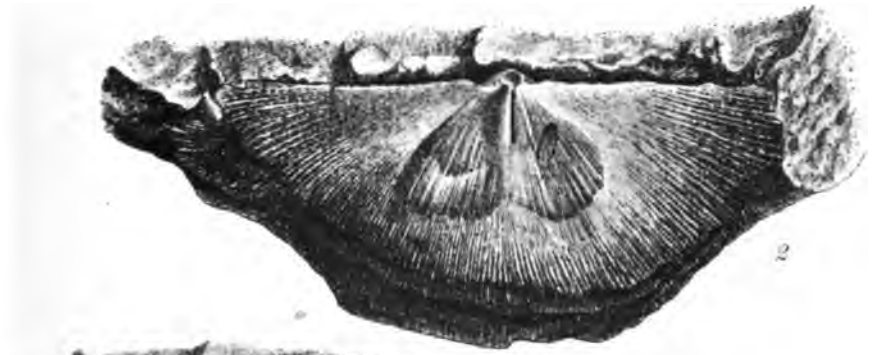
Fig. 2. Internal cast, showing the straight hinge-line, the radiate internal ornamentation, the cast of the septum, and the large faintly developed diductor scars.

Fig. 3. Partially decorticated specimen.

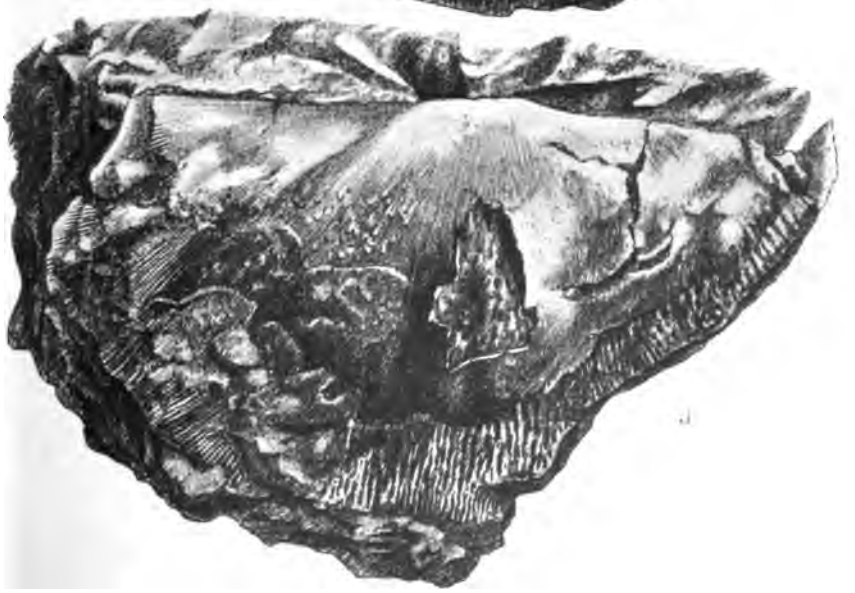
Drawn from nature by Mr. F. R. Leggatt.



1



2



3

PLATE XX.

Chonetes aspinosa, sp. nov.

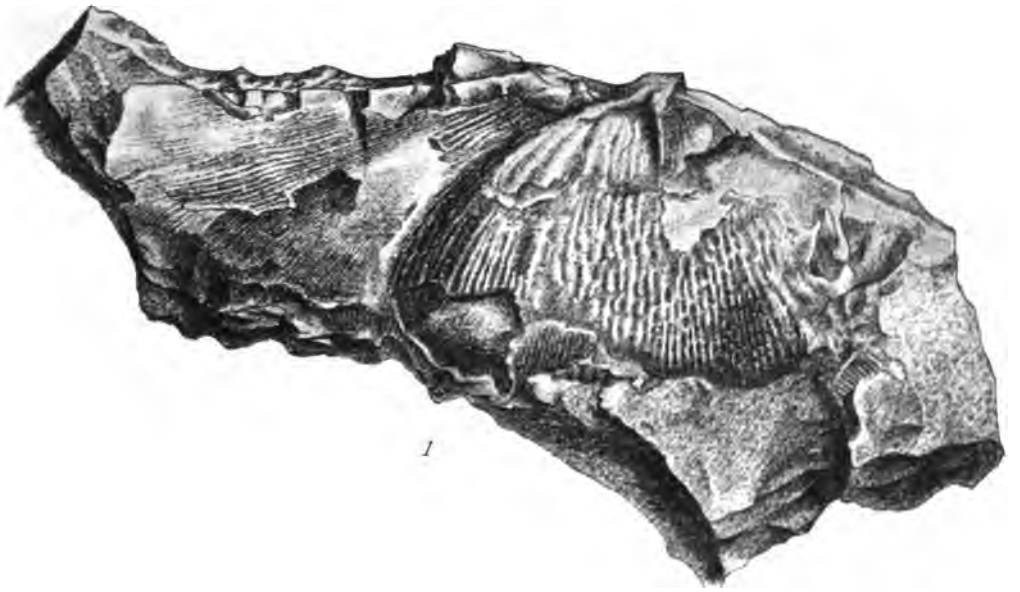
Fig. 1. Partially decorticated very wide example, showing the median septum and the interior ornamentation.

Fig. 2. Mould of part of specimen (Pl. XIX, fig. 2), showing the cardinal teeth the short septum, and the upper portion of the flabellate diductor scars.

Fig. 4. Decorticated pedicle valve, much compressed and wrinkled, showing the cast of the septum and diductor scars.

Fig. 5. Partially decorticated specimen, showing the finely striated nature of the shell and the degree of convexity.

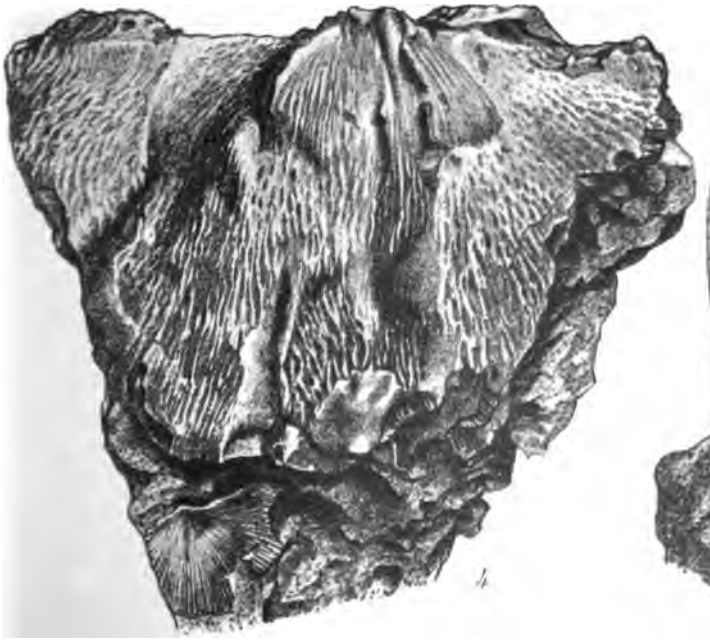
Drawn from nature by Mr. F. R. Leggatt.



1

2

3



4

5

PLATE XXI.

Carboniferous Brachiopods from Clarence Town.

Leptæna analoga.

Fig. 1. Internal impression of brachial valve.

Fig. 2. Ditto ditto.

Fig. 3. Internal impression of portion of a pedicle valve, showing the areas occupied by the adductor and anterior diductor scars.

Schizophoria resupinata.

Figs. 4, 7, 8. Internal casts of a brachial valve, showing the impressions of the anterior and posterior adductor scars, the septum, and the spaces representing the cardinal process and the crura.

Figs. 5, 6, 9. Internal casts of pedicle valves, showing the adductor and diductor muscle scars and the vascular sinuses.

Rhipidomella australis.

Fig. 10. Internal cast of a brachial valve, showing the anterior and posterior adductor scars, the separation but slightly marked.

Fig. 11. Internal cast of a pedicle valve, showing the large flabelliform anterior and posterior diductor scars, and the central elongated area occupied by the anterior adductors.

Dielasma, sp. ind.

Fig. 12. An undetermined species of Dielasma, showing a ridged surface.

Dielasma sacculum, var. *hastatum.*

Fig. 13. Cast, showing the well marked peduncular foramen and the position of the septa and crura.

Strophalosia, sp. ind.

Fig. 14. Impression of a brachial value, distorted.

Spiriferina cristata.

Fig. 15. Cast, showing well marked septum, &c.

Fig. 16. The same, viewed from the front.

Actinoconchus planosulcatus.

Fig. 17. Specimen, showing partly decorticated brachial valve, and the well developed lamellar finger.

Syringothyris exsuperans.

Fig. 18. Specimen, showing the high area and large foramen.

All figures natural size. Drawn from nature by Mr. F. R. Leggatt.

1

2

4

5

6

10

12

11

14

7

13

15

8

3

16

17

18

9

Frank R. Leggatt, del.

PLATE XXII.

Carboniferous Brachiopods from Clarence Town.

Spirifera pinguis.

Fig. 1. Pedicle valve, almost entirely decorticated.

Fig. 2. Internal cast of a pedicle valve, showing the attachment scars of the adductor and diductor muscles.

Fig. 5. Pedicle valve of small individual.

Reticularia lineata.

Figs. 3 and 4. Internal casts, showing pedicle valves with large septal plate.

Spirifera striata.

Figs. 6 and 7. Internal casts of brachial valve.

Fig. 8. Internal cast of pedicle valve.

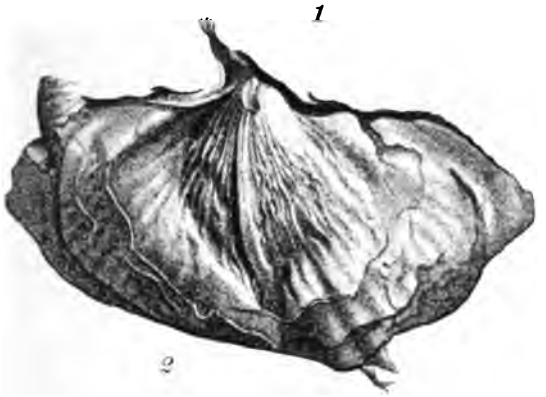
Spirifera striata (?).

Fig. 9. Compressed specimen, showing the two valves in apposition; there are fewer ribs on the medial sulcus than are to be seen in the other specimens figured.

1

3

4



2

5

6

7

8

9

Frank R. Leggatt, del.

PLATE XXIII.

Carboniferous Fossils from Clarence Town.

Productus pustulosus.

Fig. 1. Pedicle valve, somewhat distorted.

Fig. 2. Brachial valve.

Fig. 3. Brachial valve, showing the cardinal process and delicate finger of spines.

Fig. 14. Portion of pustular surface of Fig. 1, enlarged.

Productus semireticulatus.

Fig. 4. Compressed pedicle valve.

Fig. 5. The same, showing two well developed spines.

Fig. 6. Internal cast of a pedicle valve, showing the vascular markings.

Figs. 7 and 9. Impressions, brachial valves of small individuals.

Fig. 8. Pedicle valve, small individual.

Rhynchonella pleurodon.

Fig. 10. Internal cast, showing the position of the septum.

Fig. 18. Pedicle valve of a more highly costate form, showing the dental plates.

Orthothetes crenistria.

Fig. 11. Internal cast of a pedicle valve.

Actinoconchus planosulcata.

Fig. 12. Valve of young individual.

Fig. 15. Internal cast of pedicle valve.

1

11

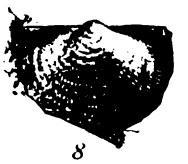
10

4

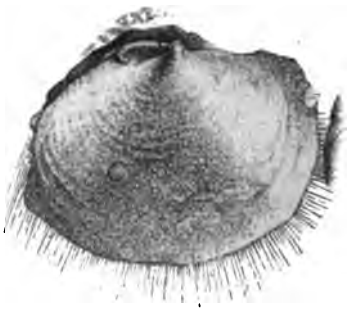
2

15

7



8



3

6

9

5

12

13

14

Frank R. Leggatt, del.

PLATE XXIV.

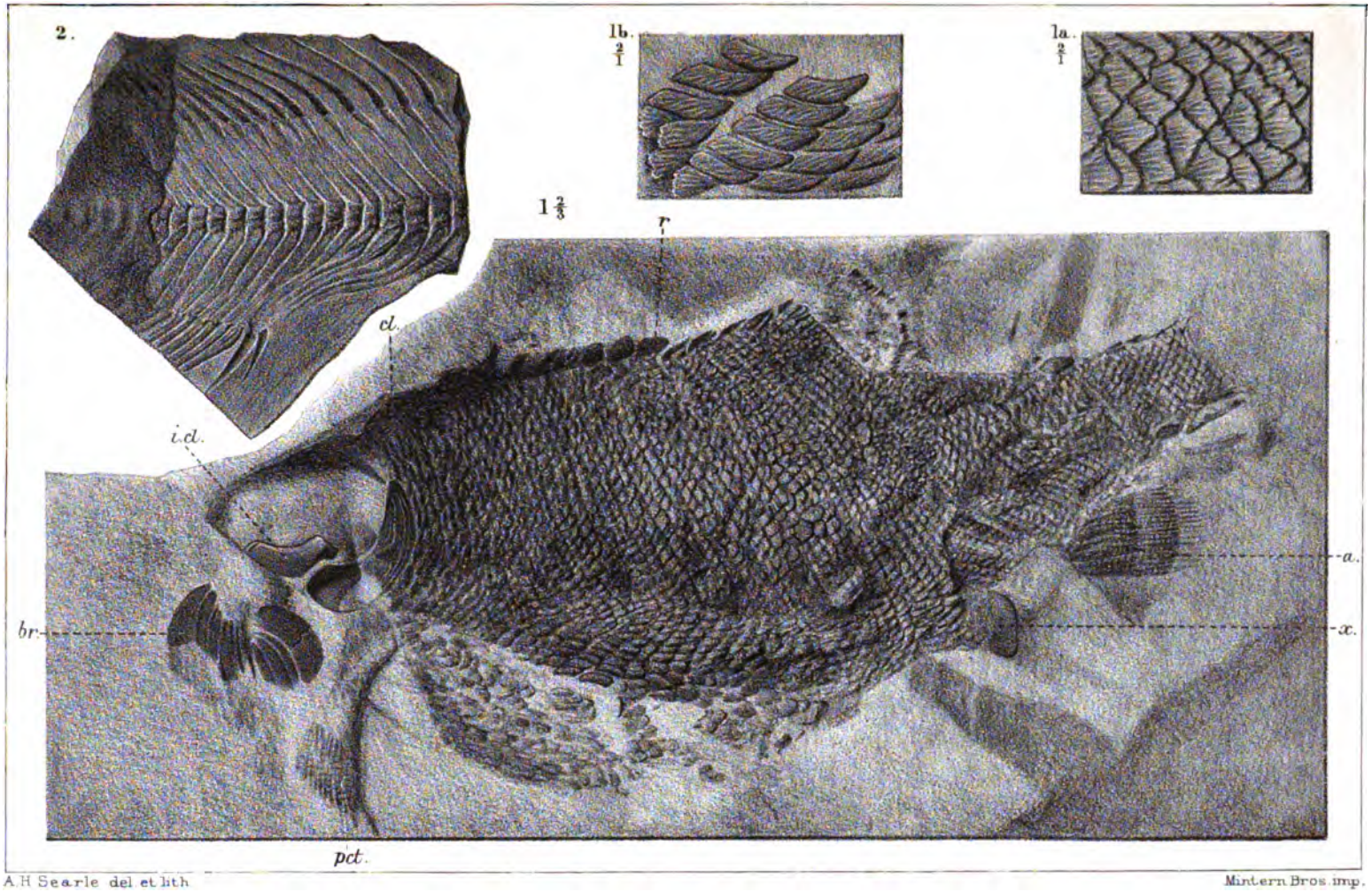
Atherstonia australis, sp. nov.

Fig. 1. Left lateral aspect of imperfect fish, two-thirds nat. size, with scales of flank (1*a*) and ventral scales (1*b*) enlarged twice. Hawkesbury Sandstone; Harrington.

a. anal fin; *br*. branchiostegal rays; *cl*. clavicle; *i. cl*. infrac-lavicles; *pct*. pectoral fin; *r*. dorsal ridge-scales; *x*. enlarged scale.

Ctenolates avus, sp. nov.

Fig 2. Right lateral aspect of imperfect skeleton, nat. size. Freshwater Tertiary; Nimbin, Richmond River.



A.H. Searle del. et lith. Mintern Bros. imp.

1. ATHERSTONIA AUSTRALIS. 2. CTENOLATES AVUS.

PLATE XXV.

Productus barringtonensis, sp. nov.

Fig. 1. Cast of interior of pedicle valve, showing attachment areas of adductor and diductor muscles.

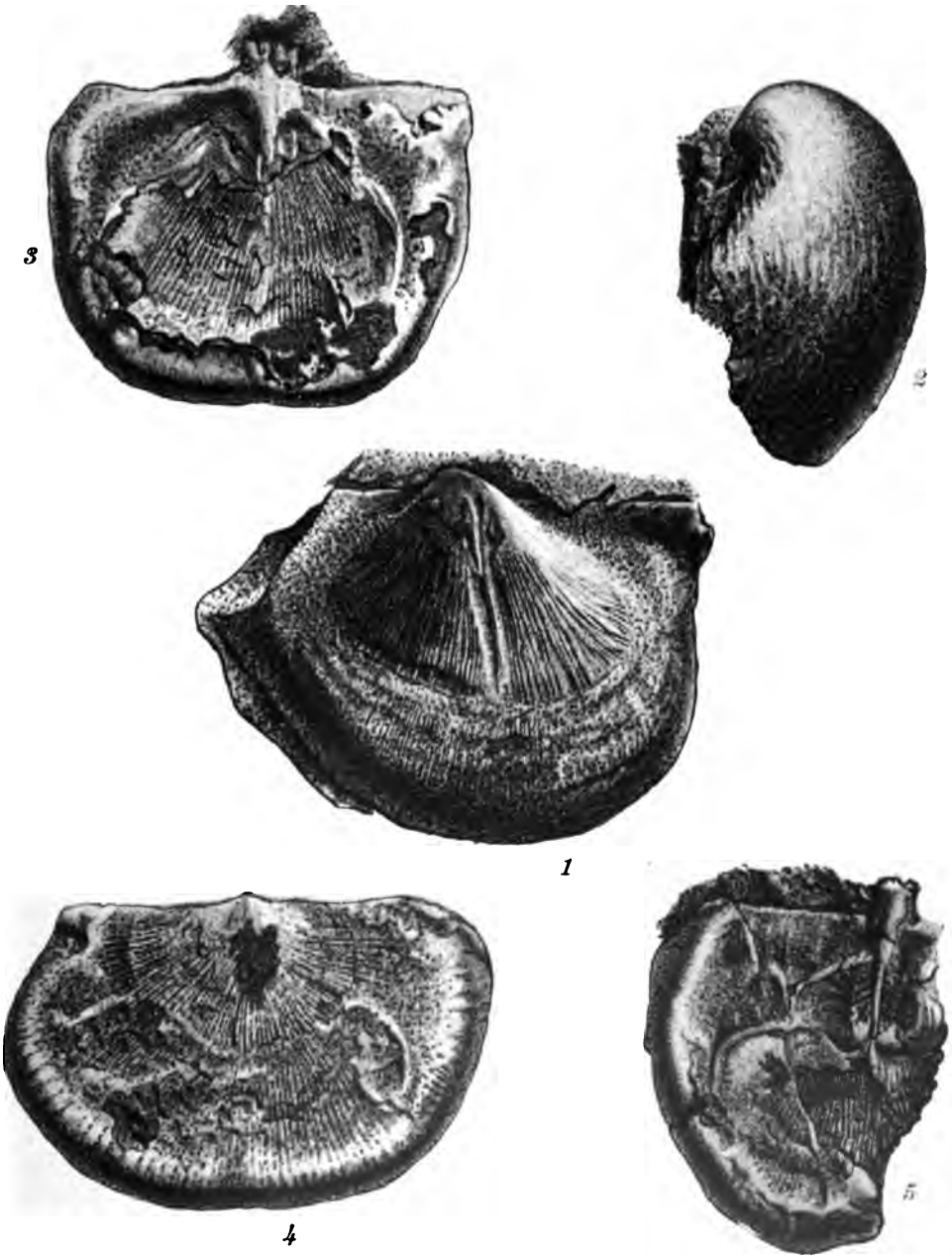
Fig. 2. Pedicle valve in profile.

Fig. 3. Interior of brachial valve, showing the cardinal process and septum.

Fig. 4. External view of brachial valve.

Fig. 5. Portion of brachial valve, seen from within, showing the cardinal process and portion of the dendroid attachment scars of the anterior adductors the position of portion of one brachial ridge and of the septum.

All figures natural size; drawn from nature by Mr. F. R. Leggatt.



Frank R. Leggatt, del.

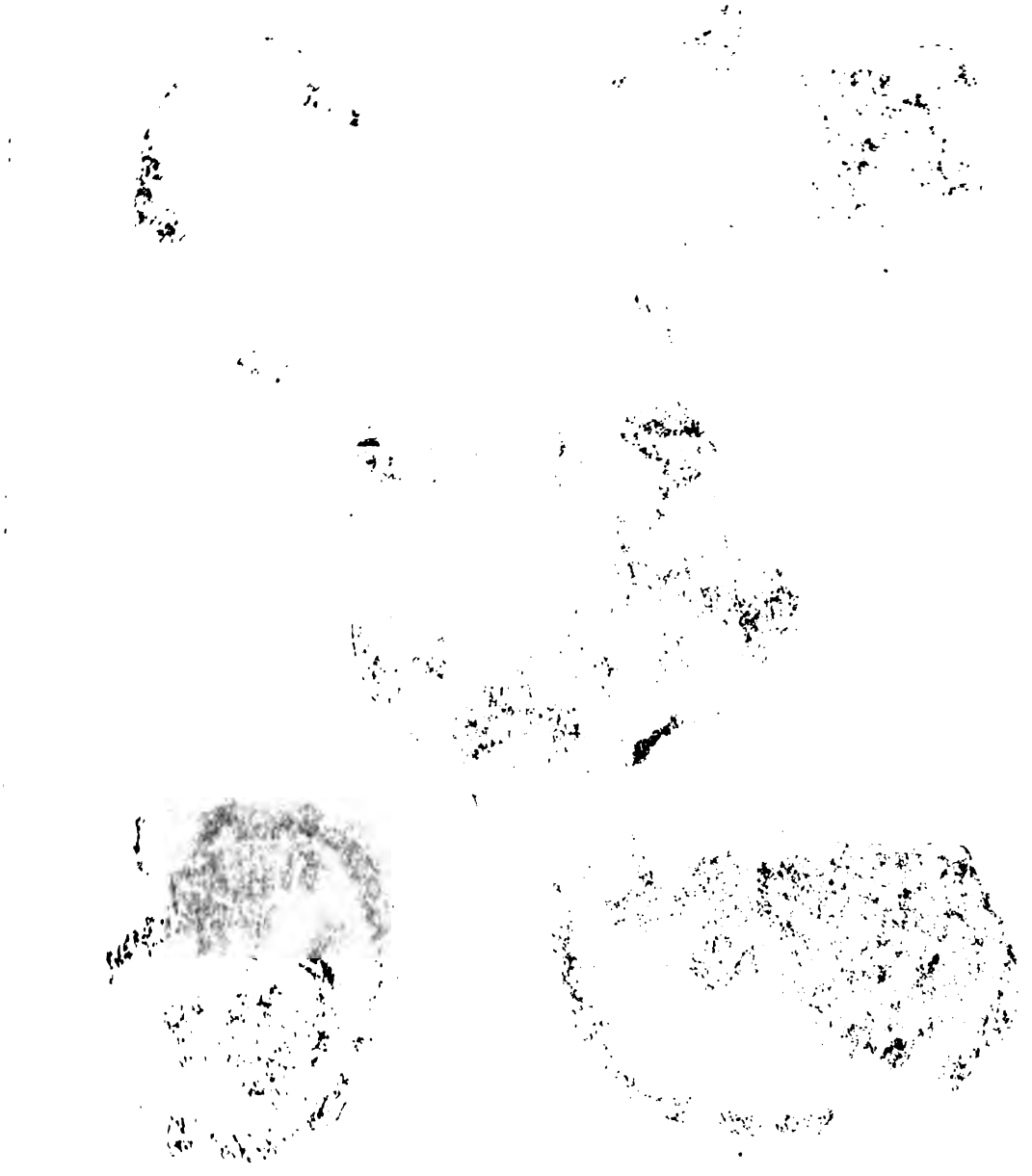


PLATE XXVI.

Analcite-Basalt from the Canterbury Dyke, near Sydney.

Fig. 1. Brögger diagram, showing composition of the rock—the basicity, large proportion of alkaline earths and iron oxides, and predominance of soda over potash.

Fig. 2. Mügge diagram, showing composition and constitution of the rock. It is seen that there is a slight excess of alumina after satisfying the alkalies.

Fig. 3. Photo-micrograph. Slide 1997A, × 36. Phenocrysts of olivine, serpentinised along cracks and where corroded, are embedded in a holocrystalline matrix of granular augite and magnetite, together with some felspar microlites and much interstitial analcite traversed by acicular inclusions.

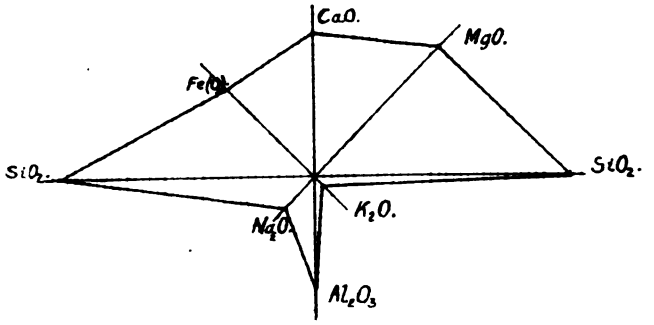


Fig. 1.

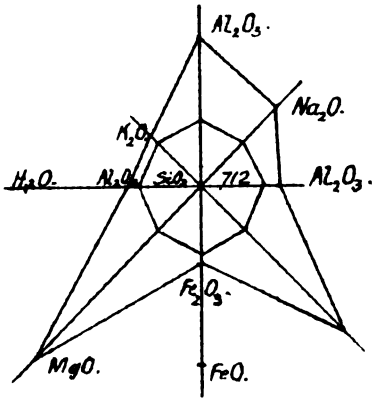


Fig. 2.

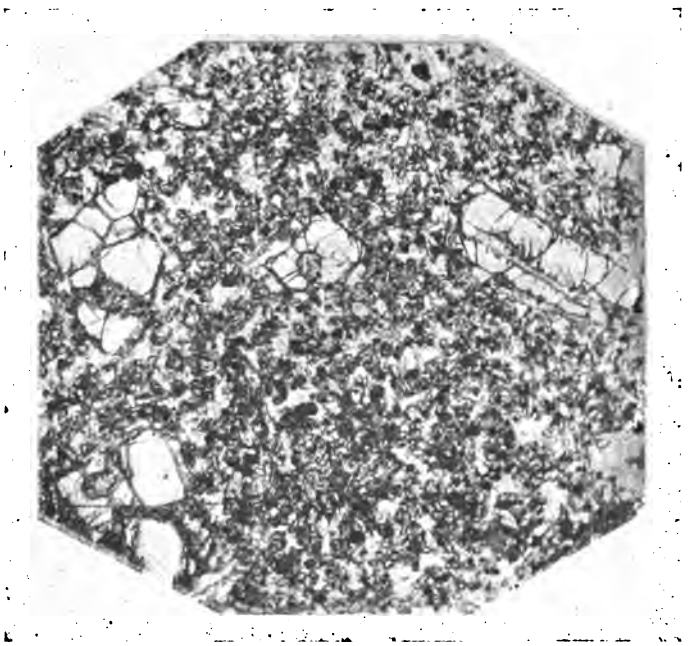


Fig. 3.

79941

Photo-lithographed by
W. A. Gullick, Government Printer,
Sydney, N.S.W.

DEPARTMENT OF MINES AND AGRICULTURE, SYDNEY.

RECORDS

OF THE

GEOLOGICAL SURVEY OF NEW SOUTH WALES.

Vol. VII.] SEPTEMBER, 1903. [Part 3.

XVIII.—The Geology of the Cambewarra Range, New South Wales, with especial reference to the Volcanic Rocks: by GEORGE W. CARD, A.R.S.M., F.G.S., Curator and Mineralogist, and J. B. JAQUET, A.R.S.M., F.G.S., Geological Surveyor.

(Analyses by J. C. H. MINGAYE, F.I.C., F.C.S., Analyst to the Department of Mines, and H. P. WHITE, Assistant Analyst.)

[Plates XXVII—XXX.]

CONTENTS.

	Page.
I.—GENERAL DESCRIPTION...	103
II.—BEDDED ROCKS...	106
Shales and Argillaceous Sandstones	106
Red Tuffs	106
Trachyte Flow	109
Basaltic Andesites..	115
Upper Tuffs	115
Upper Coal Measures	116
Basalt Flow	117
Hawkesbury Sandstone	117
III.—INTRUSIVE ROCKS	118
Introduction	118
Lamprophyre Necks	119
Lamprophyre Dykes	127
Andesitic Dykes	131
IV.—SUMMARY	135
V.—GLOSSARY	139

I.—GENERAL DESCRIPTION.

THE Cambewarra Mountains are situated at the southern end of the Illawarra Range, and are easily reached from the towns of Nowra and Berry. They have, probably, been examined from time to time in a more or less cursory manner by

many geologists; but the only paper or report having reference to them with which we are acquainted is that by Professor T. W. E. David and G. A. Stonier, published in 1890, upon the "Coal Measures of the Shoalhaven District."* In this report there is a brief reference to the Cambewarra Range.

Towards the end of last year, the Government Geologist issued instructions for a comprehensive survey of the Southern Coal-field to be commenced. This work is being carried out by one of the Authors, J. B. Jaquet, in conjunction with Mr. L. F. Harper, Field Assistant, and the petrological work incidental to the survey by the other author, G. W. Card.

The map included with this paper is a reduced sketch prepared from one of a series which will be published from time to time as the survey progresses. It covers the whole of the Parish of Cambewarra, and a portion of the Parishes of Bugong, Illaroo, Bunberra, Broughton, and Coolangatta, all in the County of Camden, and was mainly prepared with a view of showing four southern outliers of the Upper Coal Measures, and the south-western portion of those great beds of volcanic rocks which occur above the Upper Marine Series over a large area of the Illawarra District. The extension of these beds in north-eastern direction to Jamberoo and Kiama will be shown upon another map.

TABLE of formations in descending order:—

Triassic—
- Hawkesbury Sandstone Stage.
- Olivine Basalt flow.

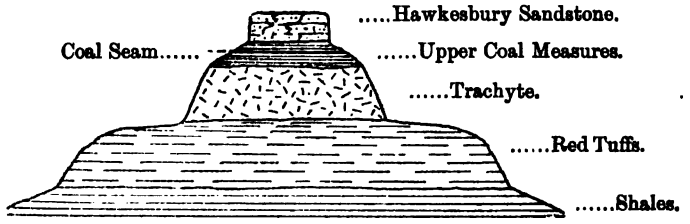
Permo-Carboniferous Series:—
- Upper (Newcastle) Coal Measures.
- Upper tuffs.
- Trachyte flow.
- Red tuffs.
- Shales and argillaceous sandstones.

The mountains rise abruptly from the coastal plains upon the east and the Shoalhaven Valley upon the south to a height of two thousand feet, and the various formations can be seen outcropping in succession down the sides. Deep valleys have cut into the range from all directions, and the upper members of the series have been in a great measure denuded away, and are only represented to-day by four flat-topped outliers or miniature table-lands:—Cambewarra Mountain, Good Dog Mountain, Kangaroo Mountain, and Broughton Head.

The outcrops of the several formations assume different forms as the result of weathering. Some stand out prominently as cliffs, others as more or less inclined slopes; and in many places, as one views the valley sides from a distance, the various rocks can be distinguished by this alternation of cliff and slope.

* Ann. Rept. Dept. Mines and Agric. for 1890, pp. 244–255.

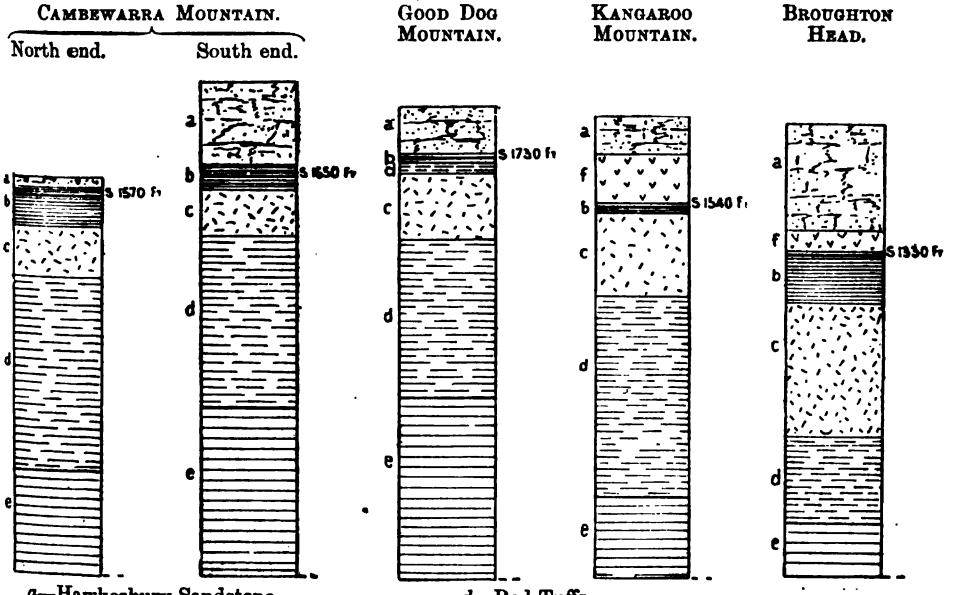
Fig. 1.—Ideal section through an outlier:—



At the summit we have a cliff of Hawkesbury Sandstone, from fifty to three hundred feet high. Below the cliff is a slope representing the outcrop of the shales, &c., belonging to the Upper Coal Measures. Next in succession we find the trachyte with a precipitous slope, or even a cliff. Along the top of the red tuffs we generally find a slightly-inclined plateau or shelf, while the edges of the formation are represented by a cliff or steeply-inclined slope. Below this cliff are slopes composed of shales and argillaceous sandstones.

As one would expect to be the case, the soils derived from the several rocks vary greatly in character and quality. Those upon the table-lands, being derived from the Hawkesbury Sandstone, are sandy. They yield a rank grass and herbage, which is of little value to the grazier. The slopes upon the Coal Measures are fairly good for grazing purposes. The trachyte yields a rich soil, but its value is discountenanced by the steep rocky slopes upon which it rests. Certainly the most valuable land is to be found upon the plateau at the top of the tuffs; for these rocks themselves yield a rich red soil, which is here enriched by fertilising material washed down from the trachyte above. The foot hills of the range and the plains below are coated with a rich soil which has been in part derived from the volcanic rocks above.

Fig. 2.—Vertical sections through outliers, Cambewarra Range:—



a—Hawkesbury Sandstone.
b—Newcastle-Bulli Coal Measures.
c—Trachyte Flow.
d—Red Tuffs.
e—Argillaceous Sandstones and Crinoidal Shales.
f—Basalt Flow.

The above sections show the thickness of the beds upon the outliers and also yield general information as to their dip. The reader's attention might be directed to the coal seam as an easily recognisable horizon. The seam reaches its greatest altitude, 1,730 feet above sea-level, at Good Dog Mountain, and from this point steadily dips in a north-easterly direction to Broughton Head, where the altitude is 1,330 feet. It also dips in a westerly direction from Good Dog Mountain, and below the Cambewarra Trigonometrical Station is found at an altitude of 1,650 feet.

The petrographical descriptions included in this paper contain a limited number of terms which have been found generally useful to avoid circumlocution, but which may not be familiar to all. A glossary of terms has therefore been appended.

II.—Bedded Rocks.

SHALES AND ARGILLACEOUS SANDSTONES.

These rocks encircle the other formations upon all sides except the north. The shales in their unaltered state are dark-grey in colour, and, where weathered, various shades of brown. They readily split into laminæ, and in this respect, and in containing less sand, differ from the normal rocks of the Upper Marine Series. Mica is invariably present in considerable quantity, and in places there is a certain admixture of tuffaceous material.

Professor T. W. E. David has described the shales under the heading "Encrinital Beds," and states that, as regards lithological character and contained fossils, they much resemble the beds of Louth Park, Maitland (crinoidal shales). The shales of Nowra and Berry are certainly homotaxial with the crinoidal shales. They cannot, however, be identified lithologically over a wide area. Upon the western boundary of the map in the Kangaroo Valley, Broger's Creek, and elsewhere, they pass into argillaceous sandstones, and lose their shaly character. Encrinites were not found in abundance, and the fossils collected consisted entirely of forms common to the whole Upper Marine Series, such as *Fenestella fossula*, *Martiniopsis subradiata*, *Productus brachythærus*, &c. Good sections of the shale beds are to be seen in the cuttings upon the Nowra-Moss Vale road between the four and five mile posts. Here they are about 720 feet thick, and extend upwards to an altitude of 760 feet. Upon the slopes of Good Dog Mountain, in the vicinity of the large intrusion of Lamprophyre, they are much metamorphosed, and the upper beds are here composed of a compact, bluish-grey quartzite. Near the town of Nowra, the shales rest upon coarse grits and sandstones. These have been called by Professor T. W. E. David the "Nowra Grits," and he suggests that they may be the equivalent of the Muree rock in the Maitland District.

*THE RED TUFFS.**

This formation varies in thickness from 350 to 690 feet. It is met with upon the Nowra-Moss Vale road at an elevation of 760 feet, and has here a thickness of 690 feet. Towards the east it is terminated by the sides of the range, but it

*The Red Tuffs of the Cambewarra Range are not identical with those of Kiama, but occur higher up in the volcanic series.

must at one time have extended far over the coastal plain in this direction, since we find it capping Coolangatta Mountain. Upon the west it loses its distinctive tuffaceous character, becomes more argillaceous, and passes by insensible gradations into the normal Upper Marine rocks. It extends northwards far beyond the confines of our map, and has yet to be traced and mapped in this direction.

The lower beds were undoubtedly deposited in marine waters, since they include numerous remains of *Spirifera*, *Productus*, *Pecton*, &c.; and, indeed, the great bulk of the formation is probably of marine origin. In the upper beds, however, the marine shells are absent, and in their place we find coaly plant remains.

So it would seem that the volcanic ashes were first deposited upon a rising sea-bottom, and finally upon a land surface, or in an estuary, or fresh-water lagoon. The tuffs may, in fact, be considered as beds of passage between the lower, unproductive, marine formation, and the upper, productive Coal Measures.

The line of demarcation between the tuffs and the underlying shales is seldom well defined; more often the two formations merge into one another, forming a bed intermediate in character, and from twenty to sixty feet thick.

Interstratified with the tuffs are narrow bands of shale and conglomerate.

The unaltered rock is either dirty green or purple in colour, and the weathered rock various shades of red and yellow. Planes of stratification can generally be distinguished. The component grains are fairly uniform in size, and for the most part approximate to that of a small pin's head, though in some localities we find them much finer, and in others coarser.

A microscopic examination has shown the particles to consist mainly of felspar—both orthoclase and plagioclase—together with quartz, augite, hornblende, apatite, and trachytic lapilli. The rock would seem to be essentially a trachytic tuff.

Rock specimen 5020.* This shows an intercalated band of shale. In colour, of a prevailing greenish-grey, flecked with felspathic particles.

The grain-size is uniform and approximates to that of a small pin's-head.

5034. Compact, with grains of approximately uniform size. The tuffaceous characters i not very evident on a freshly-fractured surface. Of a prevailing green colour, weathering dirty white.

Under the microscope it is seen to consist of trachytic lapilli, felspar crystals, and a considerable quantity of brilliantly polarizing green material, some of which is undoubtedly altering hornblende. Occasional apatite, and iron ores. The lapilli, which are more or less altered, frequently show fluidally-arranged microlites of felspar. The felspar individuals are fairly fresh, and appear to be andesine.

The rock may be classified as a trachyte tuff.

5035. A ferruginous coarse tuff containing lapilli of altered trachyte.

The rock may be described as a trachyte tuff.

* This and all similar numbers throughout the paper are the reg'stration numbers of the rock specimens in the Geological Survey collections.

5036. Uniformly fine-grained. Variegated in colour. The rock is made up of more or less altered trachytic lapilli and felspar crystals. Many of the lapilli show fluidally-disposed microlites.

The rock may be described as a trachyte tuff.

5074. A boulder found lying on the neck. It is reasonable to suppose that this may have been derived from the overlying tuff beds.

The rock is bluish-grey in colour, with a fracture varying from splintery to even. It is crypto-crystalline to micro-crystalline in structure, and contains an occasional quartz crystal.

It would be known as quartz-felsite in the field.

5078. An isolated boulder in tuff.

Megascopic Characters.—Greenish-grey in colour, weathering dirty white. Fracture even to hackly. Quartz is abundant, and felspar is indicated by somewhat obscure opaque white areas.

Microscopic Characters.—Abundant angular quartz grains are embedded in, and sometimes characteristically corroded and invaded by a crypto-crystalline base. The felspathic areas are difficult to make out.

The rock may be classified as a quartz-porphyry; or by making use of two very convenient names now becoming current in America, viz., rhyolite porphyry and apo-rhyolite.

5079. Fossiliferous. It contains numerous sand grains and mica-flakes.

5111. Even in grain, averaging several to a millimetre. Of a predominant green colour, but numerous flesh-coloured grains can be seen under a lens. It is not calcareous. Plant remains are present.

Under the microscope the rock is seen to consist to a very large extent of angular felspar, which is more abundant than the microscopic inspection would have suggested. Both orthoclase and plagioclase are present, the former predominating. A moderate degree of kaolinisation is noticeable. The rock particles are to a large extent altered into serpentinous and other products, but trachyte can occasionally be recognised. Quartz and augite are present. A very small amount of biotite, which may envelope other constituents, may be seen.

The rock may be described as a trachyte tuff.

5185. A gritty rock, the tuffaceous character of which is manifest to the eye. In colour, dirty green, with an abundance of pink felspar. The specimen contains some small pebbles, one of which is five millimetres long.

Microscopic Characters.—A characteristic tuff, containing trachytic lapilli, felspar, quartz, pyroxene, and apatite. The microlites of the lapilli possess a very low extinction angle. Some of the lapilli are micro-felsitic, and may be devitrified glass. The felspar consists of orthoclase and plagioclase; but the acidity of the latter could not be determined. The former is much clouded by kaolinisation. The *moiré* appearance and obscure twinning of some of the orthoclase-like particles may indicate soda-orthoclase.

The rock is a trachyte tuff.

5197. From near the top of the bed.

Of a prevailing green tint, but flakes of white and pink felspar are visible under a lens. Gritty; uniform in grain, averaging several to a millimetre.

5216. From above the Upper Marine Beds.

Pinkish-grey in colour, weathering yellow and brown. Fine-grained; but the tuffaceous character becomes manifest under a lens. Occasionally an opaque white felspar may be noticed.

Under the microscope it is seen to be a pumice tuff, containing fragments of felspar—orthoclase in part. The groundmass is iron-stained and of a general grey colour. The pumiceous particles are isotropic.

TRACHYTE FLOW.

This great sheet of lava must at one time have flowed over the greater portion of the area covered by the geological map. It thins out and terminates upon the west near the boundary of the red tuffs. Towards the south and east it is cut off by the mountain sides; but, unlike the tuff-bed, is not found upon Coolangatta Mountain, though we have no means of ascertaining whether it did not at one time extend there, and has been subsequently denuded away. The sheet varies in thickness from 100 feet to 600 feet, and attains its maximum thickness in the vicinity of Bellawongarah.

Having regard to the great dimensions of the lava bed, one would be inclined to think it made up of a series of flows, poured out at intervals, and superimposed one upon the other, though we have found no conclusive evidence that such be the case. Near the north-eastern corner of the map, upon the northern slopes of Broughton Head, there is at the base of the trachyte a sheet of basaltic andesite. The andesite is, in some respects, analogous to the volcanic rocks of Kiama, and it may be at this point we have two flows proceeding from separate vents overlapping one another.

Megascopic Characters.

The great bulk of the rock is compact, sound, and non-vesicular; but upon the surface there is a layer composed of both amygdaloidal and rhyolite-like varieties. We also found a vesicular rock near the base upon the Berry-Kangaroo Valley Road, west of Bellawongarah; and near the western boundary of the map, where the sheet thins out and terminates, it is more or less vesicular from top to bottom. Jointing or fissility are not noticeable, the rock generally breaking promiscuously with an even fracture. The colour is dark when fresh, comprising shades of green and purple, but becomes dirty white, brownish, or light brick-red when the rock is weathered. In texture is somewhat rough. Weathered surfaces may become pitted by the dropping out of phenocrysts. Small phenocrysts of felspar may be seen sparsely scattered through the groundmass, together with smaller and still scarcer grains of black augite. The felspar is in part fresh and striated; but earthy green and limonitic pseudomorphs occur in varying abundance. The rocks are not calcareous, but may contain pyrites. Specific gravity ranges from 2·69 to 2·72.

Microscopic Characters.

Holocrystalline and porphyritic. Mineralogically it is essentially a felspar rock, a calculation based on the chemical analysis of a typical specimen indicating a high felspar percentage. As phenocrysts, some felspar, and, to a less extent, augite in crystals of moderate size, occur somewhat sparsely; while apatite and also magnetite may approximate to phenocrystic development. These lie in an orthophyric groundmass of felspar. (Pl. XVII, fig. 3.)

Felspar.—Alteration is sometimes so far advanced as to make examination very difficult. Frequently multiple twinning is clearly shown, and occasionally quite fresh crystals may occur. Whenever possible, measurements were taken, generally the extinctions of the albite lamellæ; the results pointed to labradorite. The highest angle obtained was 30°. Carlsbad twinning, either alone or in association with albite lamellæ, is not uncommon. Individuals that are clearly untwinned also occur. Becke's method was employed to determine whether the simple or untwinned felspars were orthoclase (sanidine) or not; the results were unsatisfactory, due no doubt to the alteration products affecting the optical properties of the felspar, but showed that in part these were really plagioclastic varieties. Occasionally, however, a sanidine-like, perhaps simply twinned, individual, with low double refraction, would prove to be orthoclastic. The conclusion is that the felspar phenocrysts comprise labradorite, of basicity about Ab_1An_1, and orthoclase, but that the former predominates. In one instance, a felspar showing very fine striation, and having an index of refraction lower than balsam may, perhaps, be anorthoclase. Evidence is as yet wanting as to whether the occurrence of orthoclase may be characteristic of certain parts of the flow. Zoning was not noticed. The crystals tend somewhat to merge into the groundmass which has to some extent corroded them. The effect is most noticeable at the terminations, as if the action had been more potent along the albite lamellæ. Actual invasion may occasionally be seen. Negative crystals occupied by green or brown material occur; and apatite, augite, and iron ores may be also included.

Augite.—Is scarce. It may occur either as cleaved brown masses, or in the form of alteration products. Association with the felspar phenocrysts is common. It may become almost colourless.

Apatite.—Stout prisms, often purple in colour, and striated longitudinally. These have been measured up to about a millimetre in length. The presence of apatite is most characteristic of the whole series of specimens. It is sometimes associated with the felspar and augite.

Iron Ore.—An occasional large grain associated with the other phenocrysts.

The frequent aggregation or mutual association of the above-mentioned phenocrysts seem to indicate that they are in reality xenoliths.

The Groundmass.—This is characteristically orthophyric, consisting of fairly stout felspar microlites which very rarely show any tendency to stream. The microlites are untwinned, and show parallel or very slightly inclined extinction, measuring from their longer edge: they are, therefore, probably orthoclase. Many attempts were made to apply Becke's method, but the results were unsatisfactory, due, perhaps, to the almost universal duskiness of the groundmass. While the groundmass is essentially felspathic, small plates of augite and apatite are present, and the whole is spotted with pigment spots, probably ferrite; a good deal of chloritic matter may also be present. In almost every case quartz occurs as a primary,

but interstitial, constituent. It appears to represent the final acid product of the differentiation of the crystallising magma. This residual fluid would occupy the interspaces of the consolidating mass, and finally crystallised as quartz. A calculation based on the chemical analysis indicates about 5 per cent. of free silica.

Chemical Characters.

Specimen **4998** was chosen as a representative one. It consists of altered felspa—showing simple and multiple twinning—augite, apatite, and magnetite occur as phenocrysts, either singly, or in aggregates together with chlorite. In the groundmass, in addition to the felspar, apatite, quartz, chlorite, iron ores, together with a little calcite and, perhaps, a very little biotite, are present.

A complete analysis made by Messrs. J. C. H. Mingaye, F.I.C., and H. P. White, in the Departmental Laboratory, gave the following results:—

	Weight percentage.		Molecular ratio.
Silica	59·64	.....	·994
Alumina	17·09	.....	·167
Ferric oxide	2·45	.....	15
Ferrous oxide	3·21	.....	44
Magnesia	1·66	.....	41
Lime	3·88	.....	69
Soda	3·52	.....	57
Potash	5·88	.....	62
Water (at 100° C.)	·43		
Water (above 100° C.	1·24		
Carbonic oxide	·47		
Titanic oxide	·42	.....	05
Zirconia	absent		
Phosphoric oxide	·47	.....	03
Vanadic oxide	·01		
Sulphuric oxide	absent		
Chlorine	trace		
Fluorine	?		
Sulphur (pyrites)	absent		
Chromic oxide	absent		
Nickel and Cobalt monoxides	·04		
Manganous oxide	·21	.....	03
Cuprous oxide	·01		
Baryta	·10	.....	01
Strontia	trace		
Lithia	trace		
	100·73		
Specific gravity	2·698.		

The following points may be noticed in this analysis:—

1. Silica is perhaps a little low for a typical trachyte.
2. Alkalies are rather high—9·4. Molecularly potash and soda are about equal.
3. Lime, magnesia, and ferrous oxide are high for a typical trachyte.

Calculating from this analysis, the following percentage constitution in simple mineral molecules is obtained—the "norm." *

Quartz	6·90
Orthoclase	34·47
Albite	29·87
Anorthite	13·34
Hypersthene	7·76
Magnetite	3·48
Ilmenite	·75
Apatite	·93
Calcite	1·10
Water	1·67

To arrive at the exact mineralogical constitution of the rock, a rearrangement of anorthite is necessary to provide the alumina and lime necessary to form, in combination with the hypersthene molecules, the pyroxene actually present. Bearing this in mind it would appear (1) that the average plagioclase would be a soda-lime variety, that is to say, an andesine; and (2) that while plagioclase may predominate over orthoclase, it is not in very great excess. As, however, the microscopical evidence is in favour of some at least of the felspar being labradorite of composition Ab_1An_1, a more acid variety than andesine may be present, or the orthoclase itself may be a soda variety.

Classification.

In Europe, rocks occupying an intermediate position between trachytes and andesites have been termed trachy-andesite, trachy-dolerite, and labradorite trachyte by various writers, while Washington has described a similar series of rocks from Italy under the name of vulsinite. †The absarokite-shoshonite-banakite series, described by Iddings from the Yellowstone Park, contains members agreeing very closely, both chemically and mineralogically. Ransome,‡ in describing the lava flows of the Sierra Nevada, California, has suggested, now that the absolute necessity of a new family (Monzonite), of equal rank to, and intermediate character between syenite and diorite, has been generally recognised, that a similar comprehensive term to comprise all the effusive forms of the monzonite magma should be introduced, and uses "latite" for this purpose. In a general table at the end of these notes will be found analyses and brief petrographical descriptions of several of these analogous foreign types.

Trachy-andesite and andesitic trachyte are open to the objection that the plagioclase felspar present is labradorite. Trachy-dolerite is, in the Writers' opinion, very objectionable, as the rocks are in no sense doleritic in appearance.

* The new system of classification introduced by Messrs. Cross, Iddings, Pirrson, and Washington (Journ. Geology, 1902, No. 6), was received in time for use in connection with this work, and one or two terms, such as "norm," have been utilised. The methods of calculation recommended by these authors have been uniformly followed.

† Italian Petrographical Sketches, Journ. Geol., 1897, V. No. 4.

‡ Bull. U.S. Geol. Survey, No. 89.

Vulsinite, banakite, &c., are local names, applied abroad to special rocks; and it is very doubtful whether such will ever come into general use. Latite would undoubtedly be a most convenient term, but has not yet been accepted. Moreover, as has been said elsewhere, it seems probable that the time is rapidly approaching when a scientific classification of rocks will become possible; and perhaps the use of the old names that have been defined and re-defined again and again will be confined to the field. It has therefore seemed best for the present to classify the series as trachyte, using the term in the broadest possible sense.

4998. The specimen chosen for analysis. This agrees well with the general description given above.

5026. Pyritous.—The felspar phenocrysts include orthoclase and plagioclase.

5026$_1$. A blackish-grey rock, weathering dirty white. There is a strong tendency to orientation of the ground-mass microlites; it might indeed be described as fluidal. Under a high power, the ground-mass appears heterogeneous, and it may be that volcanic ash is largely present. This rock is finer in grain, and differs in several respects from the type.

5029. From the base of the flow.

It agrees with the type. The phenocrysts appear to be in part orthoclase, showing Carlsbad twinning. Pyritous.

5041 Distinct dichroism was noticed in the apatite of this specimen. The colours are deep-purple to lighter purple-brown, with $E > O$. Leucoxene appears to be present. Otherwise typical.

5042. From the middle of the flow.

This is one of the specimens that weather with a pitted surface. It shows small areas of ochreous iron oxide.

Microscopically it is typical.

The specific gravity, 2·64.

5043. The phenocrysts in this specimen are highly altered, rendering their exact determination difficult. The rock is much spotted with iron ores, particularly some of the pseudomorphs. The apatite occurs as stout purplish pleochroic individuals. The groundmass is orthophyric.

It conforms to the type in general.

5066. The felspar phenocrysts are small and sparsely distributed; here and there a larger tabular individual occurs. Orthoclase is represented as well as plagioclase. The rock in general conforms to the type.

Weathered surfaces become pitted by the dropping out of felspar phenocrysts.

5082. Phenocrysts of automorphic opaque white felspar, and occasionally of black augite, which may be associated with it, are readily noticeable. The microscopical determination of the felspars is difficult, but some orthoclase appears to be present. This specimen is one of those in which the absence of any sharp line of demarcation between phenocrysts and groundmass may be noticed. It is also an instance of the association of the phenocrysts in such a way so to suggest that they really represent xenoliths.

The specific gravity is 2·73.

5085. From the top of the flow.

A thoroughly decomposed amygdaloidal rock. Vesicles are very numerous, and are in part occupied by crystallised quartz.

5113. From the base of the flow.

A dull green rock, weathering ochreous and yellow. Felspar in glassy striated laths up to five millimetres in length is present, but sparsely only.

Both methods of M. Levy were used in the determination of the felspar phenocrysts, and all measurements pointed to labradorite. An **M** face was also found, and the extinctions indicated

the same result. No acid felspar is represented among the phenocrysts. The longer edges are fairly sharp; but the terminations are quite irregular, tending to merge into the groundmass. It would appear as if the magma had attacked the crystals along the twin planes. Augite and iron ores are enclosed by them. The augite is brownish, or altered into chloritic matter. Automorphic cleaved individuals occur. The groundmass agrees with the type.

5114. From the middle of the flow.

The felspar phenocrysts attain a length of one centimetre. They are somewhat greenish in colour, and show twin lamellation well. With a good glass the microlites of the ground-mass may be detected; and the holocrystalline character can be surmised without microscopical examination. A fair proportion of the felspar phenocrysts are seen either untwinned or show Carlsbad twinning only. The augite is diopside-like, fresh, cleaved, and twinned. It is not automorphic, and is associated with the felspar and iron ores. Quartz is, perhaps, rather more common in the groundmass than in some of the other specimens.

The specific gravity is 2·69.

5115. From the top of the flow.

A light purple decomposed rock, weathering green and yellow. Opaque cream-coloured tabular felspars and greenish secondary products are visible.

5116. From the top of the flow.

Ferruginous and much decomposed. Tabular sanidine-like phenocrysts are visible. Microscopic examination is rendered difficult by reason of the alteration undergone. Amygdales of fibrous ferruginous anisotropic material, with phenocrysts of automorphic felspar and apatite, lie in a groundmass of microlitic felspar and altered material. The microlites show no tendency to a fluidal disposition. The felspar phenocrysts agree with the type.

5117. From the top of the flow.

Much decomposed and vesicular; purplish in colour, weathering yellow. The vesicles may be lined with quartz crystals. Opaque cream-coloured tabular felspar visible.

5119. From the top of the flow.

A brecciated, coarsely-mottled purple and yellow rock, resembling a rhyolite tuff. Under the microscope the fragments are seen to consist of a cryptocrystalline groundmass, in which are embedded tiny microlites of felspar, showing straight extinction and considerable flow. In colour the fragments vary from black to yellow. The general groundmass contains a good deal of quartz.

Small phenocrysts of felspar occur, of which some are certainly plagioclase. A little shattered augite, together with some apatite and iron ore, is present.

5125. From the top of the flow.

A highly altered rock, showing tabular sanidine-like phenocrysts of felspar. Under the microscope one of the felspar phenocrysts shows a very fine twin striation, and the index of refraction is less than that of balsam. It may therefore be an orthoclase. This is one of the rare instances in which the groundmass microlites showed any tendency to flow. Otherwise it agrees with the type.

5126. From the top of the flow.

Very much decomposed. A light purple brecciated rock, weathering yellow. It is somewhat vesicular, the cavities being sometimes lined with quartz crystals. Opaque cream-coloured felspar, in more or less tabular crystals.

5183. The felspar phenocrysts are fresher than is usual in this group of rocks. An extinction angle of 30° was measured on a section of labradorite, approximately normal to **010**. Orthoclase could not be detected. The margins of the crystals are slightly rounded, or even embayed by the groundmass. There is an indication of a narrow marginal zone of more acid, untwinned material. Pericline twinning is shown. The groundmass is of the usual orthophyric type, and contains quartz.

5195. The felspar phenocrysts in this rock are rather numerous. They weather yellow, finally dropping out, thereby giving rise to a pitted surface.

Under the microscope rounded grains of what appears to be fine-grained sandstone are seen. These are not present in any other specimen.

5196. Thoroughly decomposed. Vesicular. The vesicles are very numerous, and are of all sizes up to two or three centimetres. They are highly elongated, and more or less oriented; and may be either lined with crystallised quartz or filled with compact silica. Pseudomorphs, after felspar are visible here and there.

BASALTIC ANDESITE.

Occur at northern end of Broughton Head, Rock Specimens **4997, 5190, 5191, 5192,** and **5219** at the base of the trachyte flow.

This occurs at the base of the trachyte flow.

Megascopic Characters.—A conspicuously porphyritic rock showing an abundance of striated felspar as phenocrysts varying in length up to one centimetre. These are tabular, fresh, and yellowish-green to creamy in colour in some cases, but opaque white from alteration in others. Grains of black augite occur here and there, but are scarcer and generally smaller than the felspar phenocrysts. Smaller, lath-shaped felspar is visible in the groundmass. The proportion of base to phenocrysts will be approximately 1 : 1.

5190 is vesicular; and the cavities are lined with beautiful chlorite, with sometimes an inner filling of calcite.

5191 is not nearly so vesicular, and shows a quantity of black pseudomorphs.

5192 coming from the point of contact with the underlying tuffs, is highly vesicular.

5219 is coarsely doleritic and greenish-black in colour where fresh.

Microscopic Characters—Felspar.—Generally fresh, but kaolinised in **4997**. Carlsbad, albite, and pericline twinning are common. A not infrequent combination of the Carlsbad and albite types of twinning enabled Levy's method of determination to be applied. Extinction angles of 33° and 20° were obtained, indicating a labradorite of composition near Ab_3 An_5. The crystals are corroded and embayed by the groundmass, and are often crowded with negative crystals occupied by stony or serpentinous matter. Occasional inclusions of augite exist. The negative crystals and inclusions sometimes form a marginal zone.

Augite.—Much corroded; well cleaved; pale in colour.

Pseudomorphs.—Chlorite, serpentine, and a pleochroic bronze-coloured substance giving straight extinctions, somewhat resembling bastite. In form these pseudomorphs are at times similar to olivine, but that mineral can nowhere be detected in a fresh condition. One of the pleochroic sections gave a uniaxial figure, and showed green to bronze axis-colours. The nature of the original mineral remains in doubt.

Groundmass.—Microlites of labradorite, with a little augite, in a deep-green groundmass that may be composed almost entirely of altered felspar. Iron ores are present in places. The amygdales show fine pleochroic chlorite polarising in rich blue tints. The groundmass of **5219** is distinctly holocrystalline, consisting of the same components as the phenocrysts.

The appearance of this rock is decidedly andesitic; and this view is borne out by the subordinate quantity of ferro-magnesian silicate present. On the other hand, the felspar is of a basic character. It is therefore, perhaps, best described as a basaltic andesite.

The rock offers no apparent analogy to the trachyte flow.

UPPER TUFFS.

It was only at Good Dog Mountain we found certain evidence of a distinct bed of tuffs at the base of the Coal Measures; but round the margins of the other outliers, we found the lower fresh-water beds to be largely composed of tuffaceous material. The bed is forty feet thick, and good sections are to be seen in the cuttings upon the cross road leading to Kangaroo Mountain.

UPPER (NEWCASTLE) COAL MEASURES.

The measures comprise beds of coarse sandstone, blue clay-shale, white cherty shale, and tuffaceous sandstones. They include one coal seam. Particulars concerning this seam will be given in another Survey publication.

At Good Dog Mountain the measures are only forty feet thick; and we have reason to believe that they thinned out altogether just beyond this point, and that the mountain stands near the extreme southern edge of the basin. They thicken towards the north and west.

OLIVINE-BASALT FLOW.

This is found as a sheet, from eighty to one hundred and fifty-feet thick, which flowed over the Coal Measures in the vicinity of Kangaroo Mountain and Broughton Head. It has been denuded between these outliers. The rock crops out upon all sides of Kangaroo Mountain, but only upon the north eastern and southern slopes of Broughton Head. At both localities the surface of the rock is largely hidden from view by sandstone talus which has fallen down from the overlying Hawkesbury formation. The sheet without doubt owes its origin to a period of vulcanicity distinct altogether from that which produced the trachyte. It was probably poured out early in the Triassic period. This is represented by seven specimens from different localities, viz. :—**4995, 4996, 5018, 5022, 5122, 5123, 5186.** Of these, the first six are doleritic in texture, the constituents being for the most part fairly even in grain and just visible to the unaided eye. In certain cases the alteration sometimes known as diabasic has commenced. The remaining sample, which comes from the northern slopes of Broughton Head, is finer in grain and decidedly porphyritic.

Doleritic Varieties.

4995 and 4996. Of these **4995** was not found *in situ*.

They are compact black rocks, with a tinge of green due to the presence of alteration products which are distinctly visible under a lens. The weathered surface is rather curious, resembling closely both in colour and appearance the shallow pittings so characteristic of meteorites.

Microscopic Characters.—In structure entirely resembling the specimens described below. They are in large part fresh, but the alteration of the olivine has been complete.

Olivine.—Now represented by serpentine and chlorite.

Augite.—Fresh for the most part, but may be altered into a spotted, feebly refractive grey substance. In colour it varies from brown to purplish, and is slightly pleochroic. In **4995** it is poikilitic (*see* description of **5122** below.)

Magnetite.—Moderately abundant.

5018, 5022.

Microscopic Characters.—Holocrystalline, porphyritic, ophitic.

Larger phenocrysts of fresh olivine and smaller ones of augite lie in base of felspar laths, augite, and magnetite.

Olivine.—Broadly speaking, irregular in shape, and showing little tendency to become automorphic. It is much cracked, but is practically fresh.

Augite.—Graduates from phenocrystic forms to the more lath-shaped automorphic or granular crystals of the general mass. In colour brown with a tendency to become purplish and faintly pleochroic; it may deepen in intensity marginally.

Felspar.—Labradorite. It occurs for the most part in laths, and is never phenocrystic. Perfectly fresh.

Magnetite.—In scattered crystals or rod-shaped skeleton forms.

Apatite.—In minute needles.

5122 and **5123.** **5122** differs from the foregoing in the olivine, being of a conspicuous red colour, both megascopically and under the microscope. It is not known whether this in part an original character due to the olivine being one of the varieties poor in magnesia or whether it is entirely owing to an incipient separation of iron oxides which has affected the colour without interfering with the optical characteristics.

Microscopic Characters.—Holocrystalline; not porphyritic.

Augite.—Thoroughly ophitic. At times, also, markedly poikilitic, a number of felspar laths being completely enveloped by an optically continuous individual of augite. Fresh for the most part, but may be completely altered into a homogeneous yellow material showing rather feeble double refraction, and also into a greenish, practically isotropic, substance. Colour light to purplish-brown, fully pleochroic.

Felspar (Labradorite or, possibly, even anorthite).—Certain **010** faces show composition zoning, the extinction with the **001** cleavage cracks indicating that the outer zone may be oligoclase. Pericline twinning was noticed in addition to albite. For the most part it consists of laths ophitically enveloped by augite, but an occasional crystal of larger size may be seen. One of these larger crystals shows bending.

Magnetite and *apatite* occur—the latter as needles—but are not conspicuous.

Olivine.—In **5123** this is represented by serpentinous pseudomorphs, but in **5122** alteration is much less advanced.

Basaltic variety.

5186. *Megascopic Characters.*—Black with a large tinge of green; weathers red. Fracture uneven and lumpy. Olivine distinctly visible.

Microscopic Characters.—Much olivine as phenocrysts in a groundmass consisting of small felspar laths, granular brown augite and magnetite, together with some brownish speckled glass and amygdales of analcite.

Olivine.—At times automorphic. Serpentinisation along cracks and marginally, but more than half the total mineral is fresh.

Felspar.—Minute laths of what is probably labradorite.

Magnetite.—In small crystals evenly scattered.

Analcite.—Round or polygonal. Evidently secondary. Perfectly isotropic. Generally colourless, but at times yellow. Traces of cleavage may be detected. Index of refraction less than that of balsam.

HAWKESBURY SANDSTONE.

This occurs as a capping from fifty to four hundred feet thick upon the top of the outliers. We are inclined to the opinion that these sandstones are an extension of the upper or Hawkesbury stage of the series, and not the Narrabeen or lower stage. The Narrabeen beds and the chocolate shales probably thin out southward of Jamberoo Mountain, though we should not like to speak definitely upon this point until the survey has proceeded further.

The sandstones are characteristic of those of Triassic age occurring elsewhere.

III.—Intrusive Rocks.

The area covered by intrusive rocks is small, but the rocks belong to an interesting and somewhat rare type.

I. Lamprophyre necks—

(*a*) Good Dog Mountain, south-east slopes, Reserve 5,658, Parish Cambewarra—**5019, 5030, 5031, 5067 to 5074, 5229.**

(*b*) Near north-east corner of Portion 152, Parish Illaroo **5027 to 5029.**

(*c*) Portion 72, Parish Illaroo—**5075.**

II. Lamprophyre dykes—*

(*a*) Nowra–Moss Vale road, south of Good Dog Mountain, Portions 79 and 83, Parish Illaroo—**5017.**

(*b*) Eastern slopes of Good Dog Mountain, Portions 49 and 110, Parish Bunberra, and adjoining land—**5081, 5083.**

(*c*) North of Good Dog Mountain, Portions 16 and 316, Parish Cambewarra—**5039, 5042 to 5046.**

(*d*) Beaumont Valley, four miles east of Kangaroo Valley township, Portion 71, Parish Cambewarra—**5181, 5182.**

Andesitic dykes—

(*a*) Eastern slopes of Good Dog Mountain, Reserve 5,658, and Portions 92 and 110, Parish Bunberra—**5033, 5047, 5060 to 5065, 5084.**

(*b*) Berry–Kangaroo Mountain road, two and three-quarter miles west of Berry, Portion 23, Parish Bunberra—**5112.**

(*c*) Southern boundary Portions 5 and 169, Parish Broughton—**5187.**

INTRODUCTION.

The classification of rock specimens is a most difficult matter by reason of the chaos which at present exists. Of recent years the tendency has been, whenever a thorough petrographical description has been given of the rocks of any region to erect the varieties found therein into types, to which new appellations are given. For purposes of comparison it is thus becoming necessary to have access to specimens of each new type described. It seems abundantly evident that such a condition of things can only be temporary; and indications are not wanting that the time is ripe for the construction of a system of classification and nomenclature based on scientific principles. For practical, every-day purposes it has seemed, therefore, far preferable to retain the old field names, using them in a broad sense, and indicating in the descriptions the special features of each rock.

The rocks to be described are of peculiar types, constituting transitions between other well known-families. That such intermediate families co-ordinate with diorite, &c., are absolutely necessary, is now everywhere recognised.

* Good Dog Mountain and the slopes which lead down from it are for the most part covered by a dense undergrowth, and it is probable that many dykes may yet remain undiscovered within the area so hidden from view.

Geological occurrence will not be recognised as a basis of classification and nomenclature; but chemical composition, followed by mineralogical constitution and texture, will alone be used.

In the determination of the Felspars the methods of Becke, M. Levy, and others have been followed; but use has not been made of Universal Stages.

While many points of detail will still remain to be worked out, requiring an expenditure of time incompatible with official duties, it is believed that the broad descriptions and distinctions made will be found sure.

LAMPROPHYRE NECKS.

(*a*) Good Dog Mountain.

The neck intrudes the shales and tuffs upon the south-eastern slopes of the mountain, extending upwards to a height of twelve hundred feet. The outcrop is about thirty chains long by twenty chains wide. The apparent outcrop is much larger than the true outcrop, for the flats at the base of the mountain are thickly covered with angular and sub-angular boulders, which have fallen down from above. The mountain sides are rough and precipitous, and in places inaccessible. The boundaries of the outcrop are largely hidden from view by scrub and dense undergrowth, and as shown upon the map are only approximately correct.

The typical rock (Pl. XVII., figs. 1 and 2) would appear to be a rather leucocratic type of lamprophyric quartz-bearing diorite, which is traversed by acid aplitic segregation veins on the one hand, and passes through melanocratic phases to basic pyroxenite on the other. No order of sequence pointing to a magmatic differentiation *in situ* could be made out; indeed, the most acid and the most basic specimens collected came from near together. The aplite veins ramify and otherwise papear to be intrusive, and the differentiation may have proceeded within the magma basin before injection. In the absence of chemical analysis, it is not possible to ascertain whether the aplite and the pyroxenite can be regarded as complementary.

Neglecting the extreme forms of differentiation, the characteristics of the average rock of the core may be expressed as follows:—

Microscopic Characters.

Crystallinity.—It is always porphyritic, the phenocrysts being generally pyroxene, sometimes biotite, but never felspar.

The texture of the groundmass tends to become fine-grained or even aphanitic.

Texture.—A more or less pan-automorphic granular texture is always shown, which may affect all the component minerals. Even when the ferromagnesian minerals are not distinctly automorphic, the felspathic areas resolve themselves under crossed nicols into somewhat sheaf-like groups of well-formed crystals. Orthoclase sometimes encloses the other constituents, giving rise to a poikilitic texture.

Mineralogical Constitution.—Mineralogically it is characterised by a plagioclase and monoclinic pyroxene, with varying proportions of orthoclase, hornblende, quartz, apatite, sphene, and iron ores. One or more of these, for instance, biotite and hornblende, may be entirely wanting.

Chemical Composition.

Complete analyses were made of specimens **5229** and **5019**, as representing the leucocratic and melanocratic types respectively of the core rock. Detailed descriptions will be given of these rocks later; for present purposes the following will suffice.

5229. A fine-grained mixture of plagioclase felspar—apparently labradorite, with subordinate orthoclase, hornblende, quartz apatite, sphene, and iron ores, in which are embedded sparsely-scattered phenocrysts of diopside.

	Weight percentage.		Molecular ratio.
SiO_2	57·64	.....	·961
Al_2O_3	18·28	.....	·179
Fe_2O_3	2·57	.....	16
FeO	3·68	.....	51
MgO	2·73	.....	68
CaO	6·40	.....	·114
Na_2O	4·08	.....	66
K_2O	2·03	.....	22
H_2O (100° C)	·28		
H_2O (100° C) +	1·10		
CO_2	·08		
TiO_2	·64	.....	8
ZrO_2	absent		
P_2O_5	·31	.....	2
SO_3	·08	.....	1
Cl	·02		
F_1	.....		
$S(FeS_2)$	absent		
Cr_2O_3	trace		
NiO, CoO	·04		
MnO	·25	.....	3
BaO	·09		
SrO	trace		
Li_2O	absent		
V_2O_5	·02		
	100·27		
Specific gravity	2·744		

[Analysis by Mr. H. P. White.]

Calculating from this analysis, the following approximate constitution in simple molecules is obtained, constituting the "norm":—

Quartz	7·56
Orthoclase	12·23
Albite	34·58
Anorthite	25·80
Diopside	3·84
Hypersthene	8·50
Magnetite	3·71
Ilmenite	1·21
Apatite	·62
Water	1·38

Of these, the diopside and hypersthene molecules, together with some alumina and lime from the anorthite, will constitute the particular pyroxene and amphibole present in the rock. The composition of these minerals not being known, their percentage cannot be arrived at. Bearing in mind that a portion of the anorthite given in this calculation should be transferred to pyroxene and hornblende, it will be seen—(1) that the average plagioclase felspar contains an excess of soda over lime, thus approaching andesine in general character; and (2) that soda-lime felspar predominates over orthoclase. Mineralogically, the rock is therefore allied to the quartz-diorites.

The presence of chlorine probably indicates that the apatite is a chlor-variety.

The small quantity of sphene present in the rock has been neglected, and the whole of the titanic acid estimated as iron ore.

5019. Conspicuously porphyritic by the presence of phenocrysts of diopside-like augite. The general mass of the rock consists of plagioclase, in part labradorite, with biotite, orthoclase, hornblende, apatite, and iron ores.

	Weight percentage.		Molecular ratio.
SiO_2	45·28	.....	·754
Al_2O_3	21·04	.....	·206
Fe_2O_3	5·22	.....	32
FeO	5·14	.....	71
MgO	5·53	.....	92
CaO	11·66	.....	·207
Na_2O	2·57	.....	41
K_2O	1·98	.....	21
H_2O (100° C.)	·13		
H_2O (100° C. +)	·43		
CO_2	·02		
TiO_2	·46	.....	5
ZrO_2	absent		
P_2O_5	·22	.....	1
SO_3	·04		
Cl	·06	.....	2
F	absent		
S($Fe S_2$)	absent		
Cr_2O_3	absent		
NiO, CoO	absent		
MnO	·31	.....	4
BaO	·11	.....	1
Sr O	trace		
Li_2O	present		
V_2O_5	minute trace		
	100·20		
Specific gravity	2·955		

[Analysis by Mr. H. P. White.]

Calculating from this analysis, the following constitution in simple mineral molecules, constituting the "norm," is obtained :—

Orthoclase	11·67
Albite	19·38
Anorthite	40·37
Podalite	·97
Diopside	13·12
Hypersthene	11·87
Magnetite	7·42
Ilmenite	·76
Apatite	·31

Of these simple mineral molecules, a portion of those allotted to orthoclase and anorthite will be required to furnish the alumina, potash, and lime, which, in combination with the diopside and hypersthene molecules, will form the particular varieties of biotite and pyroxene present in the rock, the composition of which is unknown.

Although this calculation must be regarded as very approximate only, it is clear that the average plagioclase contains more lime than soda. This result is in accord with the determination of labradorite microscopically.

The affinities of the core rock, regarded as a whole, are manifestly with the diorite family, the ratio of orthoclase to plagioclase being too low to admit of classification with the rocks now known as monzonite. Bearing in mind the number of varieties already noticed, and our limited knowledge of the series, it seems better, on chemical, mineralogical, and textural grounds, to apply the general term of "lamprophyre" at present, indicating the varieties by qualifying adjectives as may be necessary. Thus, augite being frequently present, augite-lamprophyre would be generally applicable.

It must not, however, be overlooked that, by the decreasing conspicuousness of the porphyritic and pan-automorphic characters, the rock grades into a normal fine-grained augite-diorite.

5019.—Very similar to **5030**, but with augite more distinctly porphyritic.

The division of biotite into optically continuous areas is very marked. It is not uncommon for an individual of biotite to envelop one of pyroxene more or less completely. (See Fig. 3.)

Fig. 3.—Envelopment of diopside by biotite :—

D, diopside; B, biotite; A, apatite; M, magnetite.

An optical examination of zoned, untwinned sections of felspar indicated the presence of an acid labradorite as a nucleus, with an outer zone of oligoclase. Lévy's method also pointed to an acid labradorite. A little orthoclase is present.

5030.—A medium-grained, prettily mottled, black and white rock, not conspicuously porphyritic. It consists of augite, biotite, and felspar, the former weathering out in black lumps.

Microscopic Characters.—Augite.—Diopside, occasionally showing a dark green skin. Extinctions up to 40° were measured. It is not appreciably automorphic. The crystals are often crowded with iron ores, biotite, and apatite.

Biotite.—In ragged, unaltered masses, showing strong pleochroism. Neighbouring patches are sometimes in optical continuity, although separated by felspar. Inclusions of diopside, iron ores, and apatite are present.

Felspar.—Fresh plagioclase, showing albite twinning, with extinctions pointing to andesine. To some extent it is automorphic, and grouped sheaf-wise in clusters. Composition zoning occurs, the outer band being sometimes orthoclase. Orthoclase also occurs separately, and may become poikilitic.

Hornblende.—As a deeply pleochroic (black to yellow-green) peripheral zone to pyroxene.

Apatite.—In fairly stout prisms.

Iron Ores.—In connection with pyroxene and biotite.

5031.—The marginal zone of the pyroxene may be more or less darkened by inclusions of foreign particles. The biotite is intensely pleochroic, and individuals may be completely separated by intervening felspar. The poikilitic disposition of the orthoclase is very noticeable. The plagioclase shows composition zoning.

5067.—Generally similar to **5069.** A little quartz was detected. Poikilitic orthoclase is again very noticeable. The colour of the pyroxene is sometimes deeper marginally.

5068.—Porphyritic by reason of phenocrysts of augite and biotite, with some white and a little pink felspar. The rock is pyritous. Specific gravity, 2·80.

Microscopic Characters.—Large phenocrysts of *augite* lie in a holocrystalline aggregate of *biotite, hornblende, plagioclase,* and *orthoclase felspar* with *apatite, quartz, iron ores,* and *sphene* as accessories. As a whole the rock is not pan-automorphic, but the plagioclase occurs as groups of crystals, round which the orthoclase is moulded.

Pyroxene.—The phenocrysts show a zone of resorption, and are otherwise altered—in particular a development of biotite takes place within them. The marginal zone in some cases consists of biotite and reedy hornblende.

Hornblende.—Shreddy, and, in part at least, of secondary origin.

Felspar.—Orthoclase dusky, plagioclase fresh.

By enveloping the latter the former tends to become poikilitic. For the most part the plagioclase appears to be a labradorite near Ab_1 An_1, but zoning is common. Baveno, Carlsbad, pericline and albite twinnings are all represented. Certain crystals showing excessively fine striation may be anorthoclase.

Biotite.—Abundant. Strongly pleochroic. Not automorphic.

5069.—The specimen shows an aplitic vein.

Melanocratic, much pyroxene and biotite being present, but felspar can be seen. On the whole the rock is even-grained and by no means coarse, but it becomes somewhat porphyritic by reason of phenocrysts of augite.

Microscopic Characters.—The rock is very fresh, consisting of very abundant automorphic green *pyroxene,* with *biotite, poikilitic orthoclase,* and *plagioclase felspar* with the sheaf-like arrangement before mentioned.

Numerous *apatite* crystals, *iron* ores and a little *sphene* occur as accessories.

Diopside.—Pale green. The crystals are automorphic and sometimes occur aggregated. Twinning occurs.

Biotite.—Less abundant than the diopside and not automorphic.

Felspar.—Constitutes more than half the rock by volume.

Orthoclase occurs as slightly clouded, amorphous plates often poikilitic or investing with regard to pyroxene and plagioclase. Plagioclase occurs as clear automorphic crystals displaying a tendency to form sheaf-like clusters. It is more abundant than the orthoclase. The extinctions indicate an acid labradorite. Composition-zoning is shown.

5089.—Representing a series of acid aplitic veins ramifying through the main rock.

Megascopic Characters.—Flesh-coloured. Rather fine in grain. Occasionally an inclusion of ferro-magnesian material may be noticed.

Microscopic Characters.—Essentially quartz and felspar with subordinate pyroxene, sphene and apatite.

An indication of crushing is indicated by the local granulation of the constituents.

Felspar.—Less abundant than quartz.

Orthoclase predominates over oligoclase, and is somewhat clouded.

Sphene.—Occurs in little wedges.

5070. *Megascopic Characters.*—A fine-grained granitoid rock. Light in colour, with black mottling due to biotite. Certain areas, very rich in biotite, represent a melanocratic phase. With the unaided eye it is seen to consist largely of glassy felspar, in which albite lamellation and zoning can be readily detected.

Microscopic Characters. —*Felspar*, with a tendency to occur in groups of more or less automorphic individuals, predominates. The remaining constituents are green *augite*, *biotite*, *sphene*, *apatite*, and *iron ores.*

Felspar.—The plagioclase is strongly zoned, with progressive extinctions. Carlsbad, albite, and pericline twinning are present. The extinctions point to andesine, but an outer envelope of orthoclase is sometimes seen. It is difficult to be absolutely certain whether orthoclase exists by itself, but it most probably does.

Augite.—Green. Sometimes well-cleaved. The smaller crystals show a tendency to become automorphic. It encloses biotite and iron ores.

Biotite.—Abundant in ragged pieces. It may enclose or be enclosed by augite.

Sphene.—In little wedges.

Apatite.—*Iron ores.*

The dark areas are seen under the microscope to be granulitic in character. They consist essentially of greenish-brown biotite, with water-clear felspar and some quartz. The transition from one type to another is rapid, yet not absolutely sharp.

5071.—A fine-grained, non-porphyritic rock, breaking with a fairly even fracture. Specific gravity, 2·63. Light in colour. Under a lens it is seen to consist of felspar with uniformly distributed specks of biotite, and occasional included masses of augite.

Microscopic Characters.—Granitoid in texture, and consisting of predominant *felspar (plagioclase* and *orthoclase)*, with *biotite*, *quartz*, *apatite*, *sphene* and *chlorite.*

Felspar.—Orthoclase is present, but difficulty was experienced in ascertaining its amount. The plagioclase also was not determined with certainty, but what measurements were made pointed to a rather acid variety. Zoning with progressive extinction is common and well marked. Carlsbad twinning is frequent; but much of the felspar showing it has an index of refraction above that of balsam and cannot, therefore, be orthoclase. Albite lamellæ are less common. No great amount of alteration is exhibited.

Quartz.—Occurs in angular grains.

Biotite.—Not very abundant. It is associated with chlorite.

Apatite.—*Sphene* and *iron ores* in small quantity.

This rock approximates to the mica-diorites.

5072.—This represents the extreme melanocratic phase of the differentiation. It is rather coarsely crystalline, and consists essentially of augite and hornblende with a little glassy white felspar.

Microscopic Characters.—A granular compound of basaltic *hornblende*, *pyroxene*, and *anorthite*, with *apatite*, *magnetite*, and *biotite.*

Hornblende.—Brown; well cleaved; extinguishes at low angles. Pleochroism is not remarkable. Diopside, apatite, and biotite occur as inclusions.

Pyroxene.—Diopside-like; it shows a tendency to become poikilitic with regard to the hornblende.

Anorthite.—A little only, as fresh crystals showing broad twin lamellæ, occurs interstitially.

Biotite.—A little only. The pleochroism is most intense, from absolutely colourless to a deep metallic brown. It is often enclosed by the hornblende.

Apatite.—Comparatively abundant as stout prisms.

5073.—Generally similar in appearance to the foregoing.

5229.—This represents a decidedly leucocratic type, and is selected as being tolerably representative of the greater portion of the neck.

Megascopic Characters.—Of a prevailing grey tint. Splits with an even fracture in any required direction. The general groundmass consists of a decidedly fine-grained mixture of automorphic glassy striated crystals of felspar, with laths of pyroxene or hornblende. In this groundmass are embedded somewhat larger masses of pyroxene, rendering the rock porphyritic to some extent. One mass of rich green diopside measures twenty-five by twenty-two centimetres. Only very occasionally does the felspar become at all conspicuous. It contains occasionally, quartz in cavities.

Microscopic Characters.—In texture the rock is granitoid to some extent, but the felspars exhibit a strong tendency to become pan-automorphic. The predominant constituent is *plagioclase felspar*, with much smaller proportions of *hornblende*, *augite*, *orthoclase*, *apatite*, *quartz*, and *sphene*. The plagioclase is fresh on the whole. A perfectly clear marginal zone may envelop a dusky nucleus. Zoning is common. Twinning on the Carlsbad, albite and pericline types is shown; but suitable combinations and sections for specific determination were not easily found in the section available. What definite results were obtained pointed to an acid labradorite. The orthoclase is cloudy and subordinate in amount. Its identity was established by Becke's method.

Hornblende.—Seldom automorphic. Axis colours green and yellow.

Apatite.—Comparatively abundant, in fairly stout crystals.

Sphene.—Little wedges occasionally.

(*b*) Near north-east corner, Portion 152, Parish Illaroo. The outcrop is covered by a dense scrub.

5027a.—A dark grey rock, weathering green on cross fractures. With the eye, abundant phenocrysts of biotite and augite are visible, while smaller ones of opaque white automorphic felspar may be seen on cut faces.

Microscopic Characters.—Phenocrysts of pyroxene, biotite, and felspar, together with some hornblende, lie in a microcrystalline groundmass of the same minerals. The tendency to pan-automorphism is very noticeable.

Augite.—Often as thoroughly automorphic, well-cleaved, diopside-like individuals. The crystals may enclose all the other constituents, and also sometimes show lines of negative crystals. In one slide an agglomeration of augite granules with some interstitial quartz was noticed.

Biotite.—At times of a rich bronze colour, with intense pleochroism. Alteration is rare, but development of magnetite with concomitant bleaching does occur.

Felspar.—Scattered crystals, fresh for the most part; but the interior may be dusky and surrounded by a clear outer zone, or a zone of alteration may be situated some little distance from the margin. It appears to be in the main labradorite, but some orthoclase is present.

Groundmass.—Granular augite, biotite, and magnetite, with little laths of labradorite, showing albite twin lamellæ.

5027b.—This rock differs in character from those hitherto described. Crystals of biotite, measuring up to 20 millimetres in length, with numerous perfectly automorphic pyroxene prisms up to 5 millimetres in length, and small white felspar, also automorphic, are embedded in a compact black base.

Microscopic Characters.—Coarser fragments of a similar rock are included. The base is a fine-grained mixture of the same three minerals that constitute the phenocrysts.

Pyroxene.—Almost colourless.

Biotite.—Abundant. Bent crystals occur. Sometimes found enveloping pyroxene crystals.

Felspar.—Abundant little automorphic phenocrysts of labradorite—a rather basic variety probably. Orthoclase was not certainly detected.

The Groundmass.—Granules of colourless pyroxene, flakes of brown biotite, and laths of felspar are uniformly disposed. The felspars display some tendency to stream.

The Inclusions.—The abrupt intersection of pyroxene phenocrysts lying on the margin shows that these are truly exogenic. While displaying a general similarity to the main lamprophyric mass of the neck, the proportion of felspar is greater.

5038/1.—A fine-grained aggregate of white felspar, biotite, and pyroxene, needing a lens for its elucidation, with occasional large automorphic phenocrysts of biotite and pyroxene. (Pl. XVII, fig. 4.)

Microscopic Characters.—Pyroxene.—Pale green. A pinacoidal cleavage may be developed. The marginal zone is sometimes dusky with alteration. Distinctly automorphic.

Biotite.—Very abundant. Of a rich metallic lustre, but may be bleached internally. Occasionally shows sagenite webs. The crystals are generally ragged.

Felspar.—Not nearly so automorphic as in some other members of this series. It consists of plagioclase—labradorite apparently—together with some orthoclase.

Sphene, apatite, iron ores, and *calcite* occur as accessories.

The rock may be classed as a mica-lamprophyre, closely resembling that from the typical locality of Kersanton, near Brest.

5038.—Not *in situ.* Flesh coloured to white. Fracture even. Jointed.

Megascopic Characters.—Black prisms of hornblende, together with felspar, are seen embedded in a felsitic base. Specific gravity, 2·47.

Microscopic Characters.—Fresh plagioclase with altered hornblende and stout apatite crystals in a felsitic groundmass. Some irregular masses of pyroxene, a fragment of quartz-porphyry are also present, and minute crystals of sphene are scattered through the groundmass, together with iron ores. One calculation based on Rosiwal's method, indicated that one-half the rock by weight consists of felspar, the remainder consisting principally of base and hornblende in the ratio of about 3 to 1.

Felspar.—The extinction angles of the albite lamellae point to an acid variety of labradorite. Carlsbad and pericline twining are also shown. Zoning due to differing degrees of acidity is very characteristic. Apatite occurs as inclusions. In general the crystals are fresh, but a more or less clouded nucleus may be present.

Hornblende.—Fibrous. Some separation of iron oxides has taken place.

The *groundmass* is crypto-crystalline, and of a brown colour.

There is a good deal of resemblance to the Hungarian rocks formerly known as labradorite trachyte.

(*c*) Upon the eastern boundary of Portion 72, Parish Illaroo.

A small isolated outcrop about half an acre in extent intrudes the shales.

Near the northern boundary of Portions 70 and 71, about twenty chains distant from the outcrop, numerous boulders of lamprophyre are scattered over the surface of the shales.

5075.

Generally similar to the foregoing. Orthoclase seems to occur as an envelope to plagioclase. Measurements were possible which enabled the latter felspar to be determined as labradorite, but the crystals are zoned.

The biotite is intensely pleochroic, the colour sometimes being of a metallic red. The basal cleavage indicates a slight crumpling which is accompanied by irregular extinction, the angle varying uniformly with the intensity of the stress. An intimate association between biotite and pyroxene may be noticed, and biotite also moulds itself on to felspar.

Aggregates of pyroxene grains associated with quartz occur.

LAMPROPHYRE DYKES.

(*a*) Nowra, Moss Vale Road, south of Good Dog Mountain, Portions 79 and 83, Parish Illaroo.

Six narrow dykes which intrude the shales. The outcrops of five of the dykes are much weathered, and we were not able to obtain from them samples suitable for the production of microscopic slides. One of the dykes is three feet wide, and unweathered, and from this we obtained 5017.

5017.

This specimen was chosen for chemical as well as microscopical study.

Megascopic Characters.—Very calcareous; andesitic in appearance. Very numerous and conspicuous blades and pencil-like prisms of hornblende lie in a greenish-grey groundmass. Crystals of about one centimetre in length are common, and one exceptionally large phenocryst attains a length of two and a half centimetres.

Microscopic Characters.—Abundant idiomorphic phenocrysts of hornblende, together with some pyroxene, in a dusky felspathic groundmass.

Hornblende.—Idiomorphic, twinned and cleaved. Sometimes in aggregations. Apatite and iron ores occur as inclusions.

γ, bluish-green; β, brownish-green; α, straw-yellow. Colour-zoning is sometimes shown.

Pyroxene.—An occasional pale green crystal, more or less obliterated by chloritic alteration.

Apatite.—May attain considerable size.

Iron ores are scattered throughout the rock.

The groundmass.—Very difficult to make out. In large part it consists of an aggregation of stumpy crystals of plagioclase felspar much clouded by alteration, but often showing a clear outer zone.

	Weight percentage.		Molecular ratio.
SiO_2	51·02	.....	·850
Al_2O_3	16·98	.....	·166
Fe_2O_3	5·52	.....	34
FeO	4·13	.....	57
MgO	4·13	.....	·103
CaO	6·37	.....	·114
Na_2O	3·61	.....	58
K_2O	2·98	.....	32
H_2O (100° C)	1·01		
H_2O (100° C +)	1·95		
CO_2	·35		
TiO_2	1·44	.....	18
ZrO_2	nil		
P_2O_5	·30	.....	2
SO_3	·19	.....	2
Cl	·03		
F	nil		
S (FeS_2)	nil		
Cr_2O_3	nil		
NiO, CoO	0·4		
CuO	trace		
MnO	·29	.....	4
BaO	·25	.....	2
SrO	trace		
Li_2O	nil		
V_2O_5	·02		
	100·61		
Specific gravity	2·788		

[Analysis by J. C. H. Mingaye.]

Calculating from this analysis the following percentages of simple mineral molecules, constituting the "norm," are obtained :—

Quartz	·78
Orthoclase	17·79
Albite	30·39
Anorthite	21·13
Diopside	7·37
Hypersthene	7·80
Ilmenite	2·74
Magnetite	7·89
Pyrite	·12
Apatite	·62
Water	2·96

Of these molecules, those of diopside and hypersthene, together with a portion of those allotted to anorthite, must be combined to form the particular hornblende and pyroxene present in the rock, the composition of which is not known. Making this allowance, it is evident (1) that the average plagioclase felspar is one in which soda predominates over lime, and, therefore, approximates to the andesine group ; and (2) that soda-lime felspar largely predominates over orthoclase. The small amount of chlorine present is probably contained by the apatite.

The rock may be classed as a Hornblende-Lamprophyre.

(*b*) Eastern slopes of Good Dog Mountain.

5081, a narrow sill from three to four feet wide occurring in the shales near northern boundary of Portion 49, Parish Bunberra. A much decomposed amygdaloidal rock, with abundant automorphic phenocrysts of hornblende up to five millimetres in length. A few chains further south a wide dyke of similar rocks occurs.

5083, a sill four feet wide in the shales. This sill is intersected by a dyke of trachyte three inches wide.—**5084**. The occurrence of a trachyte dyke in this position is particularly interesting. It indicates that the trachytic dykes had their origin either in a period of vulcanicity distinct and newer from that which produced the Lamprophyre, or, as we think more likely, in a later phase of the same period.

5083.

Megascopic Characters.—An andesitic-looking rock, showing numerous automorphic biotite and hornblende crystals in a dark green groundmass not resolvable under a lens. The biotite crystals are conspicuously hexagonal, and, in the hand specimen, vary in thickness up to two millimetres and in diameter to four millimetres. The hornblende prisms may be ten millimetres in length. The most prominent feature of the rock is the biotite, but in quantity hornblende preponderates somewhat.

The rock is very calcareous, and weathers brown and dirty green. Fracture uneven, hackly.

Microscopic Characters.—Abundant phenocrysts of *hornblende* and *biotite* in a crystalline groundmass of *felspar*, *quartz*, *magnetite*, and secondary products. *Apatite* and *augite* have not been detected. Alteration has been considerable ; it is indicated by the presence of abundance of *calcite*, *magnetite*, *serpentine*, and *chlorite*, and by the bleaching of the ferro-magnesian minerals.

Hornblende.—Much alteration, with development of serpentine or chlorite and of a coarse magnetite dust. In colour it is primarily brown, but changes to green as alteration proceeds.

Biotite.—Of a rich brown colour, much lessened in intensity where alteration is going on. The outer zone may remain comparatively unaffected while the interior is quite bleached.

The Groundmass.—Holocrystalline, consisting of abundance of felspar laths, with considerable quartz, numerous scattered crystals of magnetite, and calcite. The presence of quartz was confirmed by the uniaxial interference figure observed.

The felspars are fresh. For the most part, they show multiple twinning with an extinction angle of from 20° to 30°; others larger, and apparently untwinned, give approximately parallel extinction. Orthoclase and labradorite are, therefore, apparently both present.

Although the quartz is at times associated with areas of calcite, and, therefore, perhaps of secondary origin, it is not always so, and must be regarded as to some extent a primary constituent.

The rock may be classed as Hornblende-Mica-Lamprophyre.

(*c*) North of Good Dog Mountain.

5039, exposed upon road within Portion 316, Parish Cambewarra. The exact mode of occurrence of this rock could not be ascertained. Boulders of it are found lying on the trachyte slope. These boulders have probably been derived from a dyke which intrudes the trachyte. It is identical in character with the lamprophyre dykes intruding the tuffs and Upper Marine at the foot of Good Dog Mountain.

Megascopic Characters.—A grey rock abundantly studded with automorphic phenocrysts of black augite and of hornblende, and weathering yellow-brown. The augite phenocrysts range up to ten millimetres in length; those of hornblende are smaller, and, for the most part, pencil-shaped. The crystal form may be extremely well shown. The specimen is an andesitic in appearance.

Microscopic Characters.—Holocrystalline and porphyritic. Automorphic hornblende, pyroxene, and apatite, with iron ores lie in a groundmass of dusky felspar, the index of refraction of which is in general less than that of balsam, and which must, therefore, be regarded as orthoclase.

Pyroxene.—Both augite and diopside. The crystals are automorphic, well-cleaved and twinned. The colour is green, sometimes becoming paler centrally. An association with iron ores may be noticed.

Hornblende.—Automorphic, twinned and cleaved; α, straw; β, deep greenish-brown; γ, brownish-green.

Both augite and hornblende enclose iron ores and apatite. They occur in small shreds and crystals as well as phenocrysts.

Apatite.—Plentiful, in stout crystals, which are sometimes slightly purple in colour. One crystal with pyramidal terminations showed a purplish zone at about one-quarter of the radius from the margin.

Groundmass.—Dusky and obscure. It appears to consist in large part of orthoclase.

5044, a dyke thirty-three feet wide, intruding Upper Coal Measures exposed in road cutting within Portion 16, Parish Cambewarra.

Megascopic Characters.—A light-grey base, with very numerous prismatic hornblende crystals, averaging, perhaps, two millimetres in length, and some decomposed

yellow pseudomorphs. A melanocratic phase is assumed in one corner of the specimen, due to an aggregation of hornblende. Fractured surfaces, obtained by breaking obliquely to the jointing, are uneven.

Microscopic Characters.—Holocrystalline and porphyritic, with *hornblende*, *felspar*, and *augite* as phenocrysts. Of these, hornblende greatly predominates, and is the characteristic constituent. Small quantities of *biotite*, *sphene*, and *iron* ores are also present. The groundmass is felspathic, but obscure.

Hornblende.—In well-formed, well-cleaved, idiomorphic crystals; green in colour, but sometimes bleached.

α, straw-yellow; $\gamma = \beta > \alpha$; γ and β, green.

Twinning is common. As inclusions apatite and iron ores occur. A little biotite may be associated with it.

Augite.—A little residual material surrounded by alteration products.

Felspar.—Both orthoclase and plagioclase are present; but the rock is not fresh enough to admit of accurate determination.

Sphene occurs sparsely as little grey wedges.

As this is essentially a holocrystalline, more or less pan-automorphic, fine-grained mixture of orthoclase and plagioclase, conspicuously porphyritic by the presence of hornblende phenocrysts, it is most conveniently classed as Hornblende-Lamprophyre.

5045, dyke, three feet wide, intruding Upper Coal Measures, exposed in road-cutting within Portion 16, Parish Cambewarra. A small vein four inches wide can be seen proceeding from the larger dyke. The rock is much decomposed. It shows abundance of opaque yellowish-white material with hornblende and some very large flakes of mica (up to 10 mm.) in a bluish-grey base. The yellowish-white matter appears to represent felspar.

This rock may be classed with the Hornblende Lamprophyres.

5046, a horizontal dyke or sill, four inches thick, intruding the upper tuffs, and exposed in road-cutting within Portion 16, Parish Cambewarra. Much weathered.

(*d*) Beaumont Valley, four miles east of Kangaroo Valley.

5181 and **5182.** Two dykes which trend N. 20 W., and traverse Portions 22, 23, 71, 178, and 268, Parish Cambewarra. The dykes intrude the shales, are approximately parallel to one another, and vary in width from six to sixteen feet. Good exposures of fresh unweathered rock are to be seen in the creek running through the portions named.

5181. *Megascopic Characters.*—Trachytic in appearance and texture, bluish-grey in colour, weathering white and yellow. Fracture uneven. The rock is characterised by the presence of abundance of crystals of biotite, hornblende, and pyroxene; the first named having a diameter, up to two millimetres in the hand-specimen, while the prisms of hornblende, &c., may be four millimetres, or five millimetres in length.

Microscopic Characters.—Automorphic phenocrysts of *biotite*, *hornblende*, *augite*, and *apatite*, in a holocrystalline felspathic groundmass containing scattered needles of the same minerals.

Biotite.—Bent crystals more or less bleached. Granules of doubtful identification, of a smoky tint, and having a high index of refraction, are included.

Hornblende.—Automorphic with ragged boundaries; twinned. Green in colour.

Pyroxene.—Practically colourless, cleaved kernels with an external area of varying size of pleochroic yellow-green material with double refraction similar to that of hornblende.

Apatite.—Stout crystals of phenocrystic development.

Iron ores are scattered in moderate abundance over the rock.

The Groundmass.—Holocrystalline; consisting mainly of comparatively small felspar, so dusky from alteration that determination is difficult. Twinning is very obscure. In general appearance much of it resembles orthoclase, but Becke's method indicates that plagioclase must preponderate. Needles of the ferro-magnesian silicates and small crystals of magnetite are scattered through it.

The rock may be classed as Hornblende-Mica-Lamyrophyre, closely analogous to the foreign type gautéite.

5132. *Megascopic Characters.*—Abundant pencil-like prisms of hornblende are embedded in a greenish-grey andesitic-looking groundmass; one portion of the specimen is of a decided melanocratic character consisting almost entirely of rather coarsely crystalline hornblende and diopside with some mica. The diopside is translucent, and of a rich yellowish-green colour.

The rock is calcareous, breaks with an uneven fracture, and weathers with a dirty white surface.

Microscopic Characters.—Perfectly automorphic *hornblende*, *diopside*, *apatite*, and *magnetite* in a dusky felspathic groundmass.

Hornblende.—$\beta > \gamma > \alpha$.

α, pale yellow; β, brownish-green; γ, green. Twinning occurs. There may be an external zone of deeper colour. As inclusions apatite and magnetite occur. It sometimes forms aggregated masses.

Diopside.—Automorphic. Well-cleaved. Colourless or pale green. Apatite and magnetite occur as inclusions.

Apatite.—Crystals of considerable size occur in some quantity.

Iron Ores.—Crystals and grains of magnetite are generally distributed.

Calcite.—In masses.

Groundmass.—Most difficult to make out. The felspars show low double refraction, but the refractive index appears to be above that of Canada balsam.

The rock may be classed as Hornblende-Lamprophyre.

ANDESITIC DYKES.

(*a*) Eastern slopes of Good Dog Mountain, near western boundary of Portion 92, Parish Bunberra.

Rock specimens: 5033, 5047, 5060 to 5,065, and 5084.

A series of dykes, from two to five feet wide, exposed in the bed of a creek. The dykes intrude the shales, and the latter rocks are much altered in their vicinity.

Chemical Composition.

To arrive at an idea of the general composition of these trachytic dykes an average sample was taken by chipping specimens **5033, 5060** to **5065,** and **5084,** and an analysis made by Mr. H. P. White, with the following results:—

	Weight percentage.		Molecula ratio.
SiO_2	52·16	.....	·869
Al_2O_3	17·61	.....	·172
Fe_2O_3	2·55	.....	·16
FeO	4·75	.....	·62
MgO	2·88	.....	·72
CaO	5·85	.....	·104
Na_2O	4·25	.....	69
K_2O	2·69	.....	28
H_2O (100° C)	·35		
H_2O (100° C+)	2·75		
CO_2	2·89		
TiO_2	·76	.....	9
ZrO_2	absent		
P_2O_5	·39	.. ...	3
SO_3	·22	... ..	3
Cl	·04		
F	.....		
S (FeS_2)	·15		
Cr_2O_3	absent		
NiO, CoO. CuO.	absent		
Mn. O.	·29	.....	4
BaO	·08		
SrO	trace		
Li_2O	absent		
V_2O_5	minute trace		
	100·66		
Specific gravity	2·669		

From the molecular ratios the constitution in simple mineral molecules can be calculated as follows, constituting the "norm" of American workers:—

Magnetite	3·7 per cent.
Ilmenite	1·4 ,,
Apatite	·9 ,,
Orthoclase	15·6 ,,
Albite	36·2 ,,
Anorthite	20·8 ,,
$RSiO_3$	5·0 ,,
(Mg.Fe.) SiO_3	10·7 ,,
Quartz	·2 ,,
Water CO_2, &c., &c.	

To arrive at the actual mineral constitution, some of the molecules of anorthite, $RSiO_3$ and (Mg.Fe.) SiO_3 would have to be rearranged to form the biotite, hornblende and augite present, the composition of which is unknown. Moreover, a portion of the orthoclase molecules will be required for biotite.

The close similarity in chemical composition between the lamprophyric and andesitic dykes points to their having originated from the same magma; their present differences of texture and mineralogical constitution being due to differences in environment only. They differ considerably from the trachytic flow.

5033.

Megascopic Characters.—Lithoidal; greenish-grey in colour, weathering with a pitted surface. Small amygdales of quartz and calcite are visible, together with much biotite in stout automorphic crystals up to five millimetres in diameter.

Microscopic Characters.—Owing to the opacity of the ground mass it is difficult to say whether any isotropic material is present. Essentially it consists of a vesicular base of felted microlites of felspar, in which are embedded phenocrysts of biotite, pyroxene, and hornblende.

Biotite.—In part of a deep red-brown colour, not intensely pleochroic, and sometimes much deeper marginally. There is a tendency to bleaching, accompanied by a separation of iron ores, and a development of lenticles of calcite, and of a peripheral granular zone.

Pyroxene.—Usually a pale green residual portion enveloped by a belt, of irregular width and outline, of a dusky material. The absorption may be practically complete.

Hornblende.—A brown or green well-cleaved residual nucleus enveloped by chloritic or serpentinous material.

The biotite, pyroxene, and hornblende phenocrysts would appear to be exogenic. They may be also further represented by certain chloritic and serpentinous pseudomorphs.

Iron ores are scattered through the rock. In a granular form magnetite separates out from the biotite, with a tendency to collect in the peripheral portions.

The *groundmass* consists of a felted mass of felspar microlites showing practically straight extinction. The vesicles are sub-spherical and occupied by amygdales of quartz and calcite.

Regarding the ferro-magnesian silicates as exogenic, and the felspar microlites of the groundmass as orthoclase, the rock can be conveniently classified as an amygdaloidal Andesite.

5047.—The specimen available shows the junction with siliceous shale. It is very small, so that a re-determination may be necessary. The rock is holocrystalline, fine-grained, and light colour, weathering yellow. Under the microscope it is seen to consist of orthoclase and in plagioclase in about equal proportions, together with a little hornblende, in a felsitic base. The plagioclase, when extinctions could be measured, gave results pointing to andesine. A little apatite, and minute wedges of what appears to be sphene, are present. For the present the rock may be classified as Monzonite Porphyry.

5060 and **5061** represent one dyke, and come respectively from the centre and the selvage. There is no essential difference between them, and they will be described together.

Megascopic Characters.—Light-coloured, bluish-grey, lithoidal rocks, weathering yellow. Fracture even. Pyritous. Specific gravity, 2·52 to 2·64. Striated vitreous felspar can be readily detected with a lens, together with black augite, producing a speckled appearance. **5060** shows an area rich in augite.

Microscopic Characters.—Abundant *felspar* in a turbid micro-crystalline groundmass. As accessories *iron ores*, *apatite*, *quartz*, a little *biotite*, and *calcite*.

Felspar.—Carlsbad twinning frequent, with or without albite and pericline lamellæ. Often beautifully zoned. Notwithstanding the frequent occurrence of Carlsbad twinning, orthoclase is subordinate to plagioclase. A certain amount of turbidity is always present, never, however, affecting the whole crystal, but usually having a zonal arrangement with a tendency to become more pronounced either centrally or marginally. Judging from what measurements could be made on sections parallel to **010** and in the orthopinacoidal zone the plagioclase species would appear to vary from oligoclase to andesine. There is a tendency to a tabular development parallel to **010**. The zonary banding in some cases disappears simultaneously with the albite twinning, and is, therefore, then due to microscopic twinning; but it generally arises from increasing acidity outwards.

Chlorite.—Apparently pseudomorphous after augite. It is accompanied by magnetite.

Quartz.—In small quantity only. It is generally idiomorphic and associated with calcite. To some extent it is probably secondary.

This rock would be termed porphyrite by many. Adhering to the lines already laid down, it is preferred to classify it as andesite.

5062 and **5064**, the latter coming from near the centre of the dyke.

Megascopic Characters.—Colour light-grey, weathering green with pitted surface. Texture on the whole lithoidal, but with a tendency to become trachytic. Fracture even. Amygdaloidal and calcareous, effervescing freely. Specific gravity 2·66. **5064** shows phenocrysts (pseudomorphs), and inclusions of slate. Indeterminable with a lens.

Microscopic Characters.—Phenocrysts of apatite, with chlorite and other pseudomorphs lie in a vesicular fluidal groundmass consisting of felspar microlites and brown crypto-crystalline material, with some quartz. The vesicles are occupied by calcite. The microlites all extinguish practically straight, and stream round the amygdales and phenocrysts. Judging from the crystal form of the pseudomorphs these rerepresent original hornblende, and perhaps felspar.

The vesicles are lenticular, and, broadly speaking, have a tendency to linearity, roughly parallel to the general direction of the microlite streams.

The rock may be classed as a devitrified Andesite.

5063. *Megascopic Characters.*—Lithoidal and amygdaloidal, breaking with an uneven fracture. Colour bluish-grey, weathering green. Weathered surface strongly pitted, due to the dropping out of phenocrysts and amygdales. Much calcite.

Microscopic Characters.—Holocrystalline. Abundant hornblende phenocrysts in an amygdaloidal groundmass consisting of felted felspar microlites with crypto-crystalline material and a little quartz.

Hornblende.—Automorphic. Much altered by bleaching and development of chloritic matter. The original cleavage and colour is occasionally preserved in places.

Augite.—A large colourless crystal.

Apatite.—Stout crystals entangled in the hornblende, and also occurring in the groundmass.

Iron Ores.—Not abundant. The microlites of the groundmass extinguish practically straight.

This rock approximates to a type recently described as gautéite. For working purposes it seems better to refer to it as Hornblende Andesite.

5065. *Megascopic Characters.*—Lithoidal, greenish-grey, pyritous; weathering with a pitted surface due to the dropping out of the phenocrysts. The rock is very calcareous, and includes fragments of shale.

Microscopic Characters.—Phenocrysts (pseudomorphs) in a groundmass of crypto-crystalline material and felspar microlites, showing a markedly fluxional arrangement. The pseudomorphs are calcareous, and appear to represent, for the most part, aggregations of augite crystals that have been intruded by the groundmass; in some cases they may represent felspar. Apatite occurs in stout crystals, sometimes intimately associated with the pseudomorphs after pyroxene

The felspar microlites of the case extinguish at a very low angle. They in all cases stream round the phenocrysts, and lie in a brownish crypto-crystalline ground mass.

Regarding the ferro-magnesian silicates as exogenic and the felspar microlites as orthoclase, the rock may be described as a devitrified andesite.

5084. A three-inch dyke intersecting a sill **5083.**

Megascopic Characters.—Light bluish-grey in colour, weathering green and yellow, with a somewhat pitted surface. Fracture uneven; texture, lithoidal trachytic; specific gravity, 2·60. A few pseudomorphs, and an occasional little felspar crystal, are alone recognisable with a lens.

Microscopic Characters.—Pseudomorphous phenocrysts, after automorphic felspar, and apatite, lie in a dense brown crypto-crystalline groundmass, containing extremely small microlites of felspar and some quartz. The extinction of the microlites is practically straight; they exhibit some streaming. Some minute crystals of iron ore are present, and an occasional pseudomorph, after what is probably ferro-magnesian silicate, may be detected.

The felspar phenocrysts are so thoroughly altered that their determination is not possible, and no twinning can be detected. In habit they resemble sanidine.

The rock may be conveniently regarded as a devitrified andesite.

(*b*) Berry–Kangaroo Mountain Road, two and three-quarter miles from Berry, at altitude of 740 feet.

Dyke, two feet wide, intruding the tuffs. The dyke crosses an angle in the road, and two exposures can be seen. The rock is much weathered.

5112. A much decomposed vesicular and amygdaloidal rock of a creamy colour.

Under the microscope it is seen to consist essentially of microlites of felspar and granular augite in a devitrified ground mass. The microlites for the most part extinguish straight, or at a very low angle, but extinctions up to 20° were obtained. The rock is a devitrified augite-bearing andesite.

(*c*) Southern Boundary, Portion 5, Parish Broughton.

An ill-defined outcrop at the extreme end of basalt flow. It apparently belongs to a small boss or dyke which has intruded the Upper (Newcastle–Bulli) Coal Measures, and possibly the basalt.

5187. *Megascopic Characters.*—Rather soft, and of a dull-green colour, due to alteration; weathers reddish-brown. Fracture hackly. Minutely vesicular, with very numerous blackish amygdales.

Microscopic Characters.—Chloritic amygdales of irregular outline and fluidally-disposed microlites of felspar in a dense speckled isotropic base. A few phenocrysts of orthoclase and plagioclase are present. The microlites are very abundant, and give parallel or very low extinctions. The alteration of the base gives rise to a general brownish-green appearance.

A perfectly isotropic colourless rectangular mineral needs further investigation.

IV.—SUMMARY.

The Cambewarra Mountains are built up of alternate layers of sedimentary and igneous rocks. Their present configuration is due entirely to subaerial denudation, and in no way dependent upon mountain-making forces.

Towards the close of the Upper Marine Period, volcanoes became active. They ejected enormous quantities of ash, and finally a great sheet of trachyte.

Another bed of ashes (Upper Tuffs) was formed before the volcanic activity ceased.

During a period of comparative quietude, the Upper (Newcastle-Bulli) Coal Measures were deposited in fresh-water lagoons, and then another volcanic outburst occurred, and the sheet of basalt was poured out. It is probable that the vent from which the basic lava issued was not situated in the vicinity of the range, and that the lava flowed many miles to its present position.

One naturally looks to find the intrusive rocks occupying vents from which the volcanic rocks have been ejected. Three ancient necks and many dykes were discovered, but a study of the field relations and a comparison of the microscopic and chemical affinities of the intrusive rocks with those from the great trachyte flow has not enabled us to arrive at any very definite conclusions. Lamprophyric dykes radiate in all directions from the two necks of lamprophyre upon the southern slopes of Good Dog Mountain. These dykes and the necks undoubtedly originated during

one period of vulcanicity. Along the high ground north of the mountain we found the dykes intruding the Trachyte, Upper Tuffs and Newcastle-Bulli Coal Measures, but not the Hawkesbury Sandstone. Hence we can state definitely that the lamprophryes were intruded at the very close of the Permo-Carboniferous Period or during early Triassic times, and after the trachyte was poured out.

The andesitic intrusives probably belong to a later phase of the same period of activity which produced the lamprophyres. Andesitic dykes occur high up in the red tuffs upon the Berry-Kangaroo Valley road, intruding the coal measures at Broughton Head, and intersecting a dyke of lamprophyre upon the eastern slopes of Good-Dog Mountain.

A comparison of the chemical composition of the magmas brings out certain points of general interest. To facilitate comparison, the analyses, with molecular ratios calculated to two hundred, have been tabulated. In addition, analyses of foreign types resembling the Cambewarra trachyte are also given.

The lamprophyric dyke rock chosen for analysis was collected some distance away from the core. It exhibits no very important differences in composition from the typical core rock, and would, therefore, not seem to have assimilated much of the environing rock.

To obtain an idea of the general composition of the andesitic dykes, an average sample of several of them was taken by chipping, and analysed. There is evidently a close analogy between these dykes and the lamprophyre dyke analysed (compare columns I and II of the table). This magma is more basic and much poorer in potash than that from which the trachyte flow originated.

While the ultimate basis of comparison must be chemical composition, the mineralogical constitution is not without interest. Apatite is a constant component, usually in crystals of conspicuous size. Chlorine being generally present in determinable quantity, the apatite would appear to be in a chlor-variety. It will also be noted that certain inclusions of diopside and other fragments in the trachyte flow would appear to represent portions of lamprophyre rock that have not been perfectly assimilated. In this case, either the trachyte flow is younger than the lamprophyre intrusions, or crystallisation commenced in the magma basin and was followed by partial refusion to produce the lava flow. As has already been said, the field occurrence favours the view that the neck and dykes are of later date than the lava.

While no absolute distinction can be drawn, it is nevertheless evident that the physical conditions favoured the development of pyroxene in the neck, and of hornblende in the lamprophyre dykes. Pyroxene is, indeed, almost entirely absent in the latter.

It will be noticed that in most cases nickel and cobalt, and barium, are present in determinable quantity, while in the trachyte this is also the case with copper. The necessary elements for the production of an ore deposit are, therefore, all present in this igneous series. An assay for gold and silver of a large sample of the trachyte yielded nothing.

The vanadic oxide possibly exists in the diopside, acting as a pigment.

Of the more important rock-forming oxides, the ratio of iron, lime and magnesia is higher in the melanocratic phase of the dyke rock, a natural consequence of the differentiation of the magma. Not so easily explained is the very high ratio of potash in the trachyte. Comparing the trachyte with the typical neck-rock, the former is seen to also differ considerably from the latter in containing a much smaller proportion of magnesia and lime.

Classifying the analyses by the method recently suggested by American petrologists,* the results are as follows :—

Dyke Andesite.....	Class II, Order V, Rang 3, Sub-rang 4.
Dyke Lamprophyre.....	Class II, Order V, Rang 3, Sub-rang 4.
Neck Lamprophyre	Class II, Order V, Rang 3, Sub-rang 4.
Neck Lamprophyre ..... (Melanocratic phase.)	Class II, Order V, Rang 3, Sub-rang 4.
Trachyte flow	Class II, Order V, Rang 2, Sub-rang 3.

The effect of the altered ratio of alkalies and alkaline earths has been to place the trachyte in a different rang to the lamprophyres.

The resemblances and differences above recorded apparently point to the probability of the whole series having originated in a common magma basin; but an interval of time sufficient to allow of differentiation intervened between the extrusion of the lamprophyre and of the trachyte.

It is to be hoped that further light may be thrown on the question of genesis when the igneous series lying to the north-east of the Cambewarra area has been studied.

* Foot-note, page 112

Table of Analyses.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	Ia.	IIa.	IIIa.	IVa.	Va.	VIa.	VIIa.	VIIIa.
SiO_2	51·02	52·16	57·64	45·28	59·64	59·43	60·89	60·03	120	125	130	103	137	138	141	136
Al_2O_3	16·98	17·61	18·23	21·04	17·09	16·68	17·14	17·05	25	25	24	27	23	22	24	24
Fe_2O_3	5·52	2·55	2·57	5·22	2·45	2·54	3·32	1·83	5	2	2	4	2	2	3	1
FeO	4·13	4·75	3·68	5·14	3·21	3·43	·95	4·15	8	9	7	10	6	7	2	8
MgO	4·13	2·88	2·73	5·53	1·66	1·84	1·16	1·12	14	10	9	19	6	6	4	4
CaO	6·37	5·85	6·40	11·66	3·88	4·09	3·58	6·58	16	15	16	28	9	10	8	15
Na_2O	3·61	4·25	4·08	2·57	3·52	3·72	4·54	2·31	8	10	9	6	8	8	10	5
K_2O	2·98	2·69	2·03	1·98	5·88	5·04	5·71	5·12	4	4	3	3	9	7	8	7
H_2O (100° C)	1·01	·35	·28	·13	·43	·27	1·61	1·42	.....	.....	.....	.....	.....	.....	.....	.....
H_2O (+100° C)	1·93	2·89	1·10	·43	1·24	·72		ignition	.....	.....	.....	.....	.....	.....	.....	.....
CO	·35	2·75	·03	·02	·47	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
TiO_2	1·44	·76	·64	·46	·42	1·38	·49	.....	.....	.....	.....	.....	.....	.....	.....	.....
ZrO_2	nil	nil	nil	nil	nil	·08	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
P_2O_5	·30	·39	·31	·22	·47	·58	·27	·42	.....	.....	.....	.....	.....	.....	.....	.....
SO_3	·19	·22	·08	·04	nil	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Cl	·03	·04	·02	·06	trace	·05	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Fl	nil	nil	nil	nil	?	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
S (FeS_2)	nil	·15	nil	nil	nil	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Cr_2O_3	nil	nil	trace	nil	nil	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
NiO, CoO	·04	nil	·04	nil	·04	.....	·19	.....	.....	.....	.....	.....	.....	.....	.....	.....
MnO	·29	·29	·25	·31	·21	trace	·09	·09	.....	.....	.....	.....	.....	.....	.....	.....
CuO	.....	nil	trace	.....	·01	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
BaO	·25	·08	·09	·11	·10	·14	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
SrO	trace	trace	trace	trace	trace	trace	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Li_2O	nil	nil	nil	trace	trace	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
V_2O_5	·02	trace	·02	trace	·01	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	100·61	100·66	100·27	100·20	100·73	100·04	99·94	100·12	200	200	200	200	200	200	200	200

I. Hornblende Lamprophyre, Cambewarra: analyst, J. C. H. Mingaye.
Ia. ,, ,, ,, : molecular ratios calculated to 200.
II. Andesitic Dykes, Cambewarra: an average of several specimens. Analyst, H. P. White.
IIa. ,, ,, : molecular ratios calculated to 200.
III. Lamprophyric Diorite, Cambewarra: analyst, H. P. White.
IIIa. ,, ,, : molecular ratios calculated to 200.
IV. Augite-mica-lamprophyre, Cambewarra: analyst, H. P. White.
IVa. ,, ,, : molecular ratios calculated to 200.
V. Trachyte, Cambewarra: analysts, J. C. H. Mingaye and H. P. White.
Va. ,, ,, : molecular ratios calculated to 200.
VI. Augite-latite: analyst, Foreman.
VIa. ,, : molecular ratios calculated to 200.
VII. Quartz-Banakite: Journ. Geol., 1895, page 947.
VIIa. ,, : molecular ratios calculated to 200.
VIII. Vulsinite: Bulletin 89, U.S. Geol. Survey, page 66
VIIIa. ,, : molecular ratios calculated to 200.

V.—Glossary of Terms.

Loewinson-Lessing's Lexique Petrographique (Congrés Géologique International, 1900, 2me. fasicule) has been followed as far as possible.

Aphanitic.—Applied to a compact rock, the constituents of which are not distinctly visible to the unaided eye.

Apo-rhyolite.—The particle "apo" indicates that the rock to which it is prefixed has been derived from another by devitrification.

Amygdales.—The kernels of secondary material occupying the steam-cavities of vesicular lavas = Amygdule.

Amygdule has been more generally used, but amygdale is exclusively employed by several of the best known geologists, and is adopted by Lessing. Its appropriateness in connection with the term "amygdaloidal," applied to a rock containing amygdales, is manifest.

Automorphic.—Descriptive of a mineral when showing more or less external crystal form. Idiomorphic has been more generally used, but by using automorphic a syllable is saved, and the prefix "aut" is not uncommon in Englih, *e.g.*, autograph.

Crypto-crystalline.—A finely crystalline structure, discernible only under the microscope.

Granitoid.—Having the same crystalline structure as granite.

Lamprophyre.—Used here as a general term to include fine or moderately fine-grained rocks, characterised by an abundance of ferro-magnesian minerals.

Latite.—Proposed by Ransome as a comprehensive term to cover all the rock groups intermediate between the Trachyte and Andesite families. It is the volcanic equivalent of Monzonite.

Leucocratic.—Used in contradistinction to *melanocratic*, to indicate those portions of a differentiating magma poor in coloured constituents.

Melanocratic.—See *leucocratic.* Used to indicate those portions of a differentiating magma relatively richer in coloured constituents—in particular, the ferro-magnesian silicates. These terms are not necessarily synonymous with light and dark coloured.

Monzonite.—A rock family intermediate to, and coequal with, syenite and diorite. Plagioclastic and orthoclastic felspars should be present in approximately equal proportions.

Norm.—The term used in the recently published American system of rock classification to indicate the constitution of a rock in terms of simple mineral molecules. Complex minerals such as biotite, augite, and hornblende can be regarded as made up of simpler molecules.

Anthophyric.—A texture shown by ~~aster~~ trachytes, in which the felspars of the ground mass display short rectangular sections.

Pan-automorphic.—Indicates that approximately all the mineral constituents of a holocrystalline igneous rock are showing more or less crystallographic form = Panidiomorphic.

Phenocryst.—Term applied to any individual porphyritic crystal in an eruptive rock.

Poikilitic.—A microscopic structure, in which a larger individual of one mineral encloses a number of smaller crystalline grains of another = Pœcilitic.

Xenocryst.—A crystal foreign to the igneous rock in which it is now embedded.

Xenomorphic.—Applied to the structure of a crystalline rock in which the component minerals do not exhibit their crystallographic form = Allotriomorphic. (See *Automorphic.*)

XIX.—An Outline of the Tertiary History of New England: by E. C. ANDREWS, B.A., Geological Surveyor.

[Plates XXXI—XLI.]

Synopsis.

Page.
1. Argument 140
2. Introduction 141
3. Explanation of terms used in report 145
4. Notes on stream development 146
5. Salient features of plateau of New England and of the associated coast 151
6. Stream characteristics 166
7. Discussion 187
8. Summary 284
9. Appendix 215

Thesis.

Repeated elevation of subaerially carved and successively-formed peneplains, combined with a long period of erosion post-dating the last great uplift, is the key to the history of New England since early Tertiary or late Cretaceous time. The elevations imposed a flattened dome-shaped surface upon the area under consideration, the axis of the dome being drawn out in a meridional direction. The rocks acted upon comprise masses of such varying resistance to the agencies of erosion as granites, columnar basalts, vertically-bedded Palæozoic and horizontally-bedded Triassic sandstones and shales.

During the development of the present forms, the land has been subjected to activities so long continued that peneplains have been several times developed at

sea level, the uplift of each of which in turn has revived stream action and allowed of the development of fresh plains of erosion. Relics of surfaces so formed exist in the harder granite and basaltic areas of the table-land.

Paroxysmal volcanic activity modified stream development at various periods in Tertiary time, and considerably complicated the surface features. The growth of the present rivers shows the revival of stream activities after a late Tertiary uplift, when the cycle of denudation immediately preceding the present one had advanced to old age. In the present cycle of denudation the adjustment of streams to structure, already well advanced in the previous cycle, has been carried to a striking degree of perfection, especially in non-basaltic areas.

Recent or Pleistocene subsidence combined with a later vibratory movement of elevation, both movements post-dating the old-age dissection of the coastal extension of the plateau, accounts for the present coastal and shore topography. Criteria of pronounced sedimentation intervening between the late Tertiary uplift and recent subsidence exist in the loss sustained by the plateau through the action

CORRIGENDA.

Page 140, line 1. For "*Anthophyric*" read "*Orthophyric.*"
Page 140, line 1. For "artam" read "certain."

but fleeting forms, while more subdued surfaces or monotonous plains imply the action of erosive activities during long periods of time. In mountainous countries, youth means diversity and magnificence of form. The uplands of New England the Blue Mountains, and the Darling Downs are in a very youthful stage of dissection, and their marvellous gorges and cliffs—expressions of this youth—by reason of their diverse forms, compel the wonder and excite the curiosity of the passer-by. In the north one observes the terraced appearance of the plateau, the effect of the desolating winter wind on the same, the alternating expanses of granite plain studded with quaint tor, of curiously contorted slate or fertile lavas, mighty Phlegraean fields of old time now silent and cold, which compose its surface. These are all trenched, on their eastern borders, by numerous and wonderful V-shaped cañons, inaccessible at their heads, and several thousand feet deep but a few miles down the stream-courses from the first cascading of the torrents.

Typical of the scenery obtaining in the north-eastern portion of the uplands are the sunlit gorges of the South Clarence. Here the head waters of the river take flights over lava sheets, whose symmetrical columns form giant ramps to the natural trenches, at times clustering together as groups of pilasters or advancing into the valley as buttresses half buried in their own *débris*.

The Macleay mountain tract forms a plexus of sunless gulches, that wind through wild precipitous granite blocks, several thousands of feet in height, and basaltic ranges, clad with marvellous forest and wreathing jungle, to form an anastomosing series of defiles simulating leaf venation in plan.

Grandest of all are the peaks of the Macpherson Range, where Mounts Lindsay, Warning, Barney, and associated masses magnificently overtop the southern extension of the Darling Downs. Wondrously isolated, their fanciful outlines admit of easy study. Lindsay, although dismantled in part by time, still presents an inaccessible summit to the climber, and dominates the landscape for over seventy miles in several directions.

Thence to the coast the mountain piles dwindle in height, and become less and less separable from the gentle undulations of certain portions of the coastal areas.

West of Sydney other wondrous forms are to be found. Here the bleak sandstone plateau of the Blue Mountains yields, even under generous rains, but a reluctant vegetation. Harsh and monotonous scenes are characteristic of this upland surface. Nevertheless, it treasures in its depths cañons whose profiles present marked differences from those of the terrifying clefts of the Macleay. Waterfalls of great height occupy niches in the mighty tiers of masonry, which sweep round the valleys in parapet form and stretch away "illimitable to the horizon." Fertile shales underlie the massive sandstone ramparts, and support luxuriant vegetable growths, presenting marked contrasts to the forbidding aspect of the sterile sandstone.

What forces were set in motion to produce these forms or the gently swinging beaches, isolated peaks, and northerly deflected and bar-bound rivers of the north coast; the wealth of repeatedly ramifying fiord, sheltered lagoons and lakes with forest-clad spurs descending into their quiet waters, and the sluggish streams with jungle-clad banks of the central coastal area; or the perpendicular cliffs of sandstone and the tall rampart of the Illawarra Range in the neighbourhood of Sydney?

The undulations of the plateau, the stately outlines of the mountains, the tumultuous profiles of the cañons, and the curves of the coast have no fortuitous origin, but express the action of well-ordered processes operating through long periods of time.

By the study of topographic forms much may be ascertained concerning the history of a land surface, which the rapidly-moving observer would remain in ignorance of had recourse to be made by him for such knowledge to the details of rock structure and composition, and the gathering of fossils, perchance, contained in the rocks. The studies of surface features and old life forms are supplementary. Of the two, the former presents the more inviting field to the general student; and,

though its records are not written so indelibly in the tablets of stone as those of the latter, yet, in questions of later geological time, its evidence as to the age of a land surface is invaluable, especially in the absence of palæontological criteria. Facility of interpretation by its methods, as will be readily seen, is in an inverse ratio to the time that has elapsed since the completion of the cycle of development during which the land forms were produced, yet, without it, the chain of evidence supplied by structure and life is incomplete.

The present paper was suggested by the perusal of Sir A. Geikie's "The Scenery of Scotland," and a paper on "The Geological History of Harbours,"* by Prof. N. S. Shaler, and is the outcome of observations taken during numerous coach and cross-country rides in northern New South Wales. No pretence is made to accuracy of detailed observation, an attempt being made merely to outline the general principles along which the present forms have been evolved. All the sections and plans are approximately correct only, especially those taken across the plateau, the various intrusions of granite into the stratified rocks after pronounced earth movements twice repeated, and the great extent of the overlying lava sheets, preventing any information of real value concerning the internal structure of the plateau being obtained by the writer during his short excursions through the district. Faults and flexures of great size must have accompanied such earth movements as initiated, and, from time to time, rejuvenated the New England plateau. The mapping and correlating of such important phenomena will require careful studies of the area.

The sketch here presented to the reader of the more salient features in the history of the northern plateau and coast was undertaken with a desire to give an impetus to topographical studies in Australia. The field is broad, and errors must creep into the pioneer attempts to work out the scheme of the Tertiary development of such a vast area as New England, palæontological criteria being absent. Only by correlating the New England uplands with those of the Blue Mountains, the Darling Downs, the rolling downs of Queensland, and the high-level plains of Monaro and Victoria can such errors be eliminated. Studies conducted among the high levels of Victoria may result in undoubted palæophytological criteria of age for one or more of the old subaerial plains of denudation.

Again, it is known that the Cretaceous sea existed in Central Australia, and stretched away thence to New Guinea and New Caledonia, occupying part of the area now existing as the great Queensland cordillera. Upper Cretaceous rocks form portions of the present Queensland plateau. Much light will be thrown on the relative ages of the New England peneplains by a study of the northern levels formed in part of Cretaceous sediment, and thus of Post-Cretaceous age. The horizontal disposition of the Triassic and Cretaceous rocks elevated in late or Post-

* Ann. Rept. U.S. Geol. Survey, 1891-1892, xiii, pt. 2.

Cretaceous time allow of the ready deciphering of warping, faulting, and degradation; whereas New England, consisting of a Palæozoic complex only, with Tertiary basalts and dense jungles hiding its eastern extension, constitutes a district specially intricate to unravel as regards the exact ages of its various uplifts and subsidences.

The American school of geologists claim that sculpturing by the forces of subaerial denudation, rather than by those of marine erosion, accounts for the formation of plains of erosion. Their position is strengthened by a study of New England forms. The whole of the plateau has remained above sea-level since Triassic times. Various peneplains have been developed in the area since such time, the plains themselves rising one above the other in terrace form. Not even on the latest peneplain, in its unreduced portions, have any sign of marine strata been found. On the other hand, the broad valleys of the upland are seen to coincide with the weaker belts of rocks obtaining in the area. The evidence goes to prove a subaerial origin for these Cretaceous and Tertiary peneplains.

With respect to the basalts of New England, it may hereafter be proved that certain volcanic activities were initiated contemporaneously with the first Tertiary upheaval, and that one of the higher basaltic plains is due to the subaerial denudation instead of representing fresh lava flows after a lengthened period of erosion. The evidence, however, goes to show that the high basaltic plains of New England preserve in many instances their original surfaces of flow.

Attention is also drawn in the discussion to the wonderful series of granite intrusions and volcanic outbursts which are connected with the early and late history of New England.

The differential erosion of huge granite bosses and strata of varying hardness is dealt with in the chapter on New England stream characteristics, and attention is drawn to that belt of country some twenty to thirty miles in width, immediately to the east of the plateau margin, in connection with its influence on population. The gorges are several thousand feet deep; communication is exceedingly difficult even by following the valleys, since the stage of mature plateau dissection has not been reached. Dense jungles and forests also present obstacles to travel. There have been proposals to encourage settlement in a small way in this area. It appears evident that in the future, when New South Wales may possibly support a dense population, the mountainous belt under consideration will carry at best a scattered population of miners, large pastoralists (squatters), and lumbermen only.

Some of the auriferous deep leads have had a Cretaceous age assigned to them by earlier observers. All such, if they exist at all, must lie on the Cretaceous peneplains. Leads which have been classed as Cretaceous, but which are found to

occur on Tertiary high-level plains, must have their ages correspondingly reduced. All buried river deposits known to the writer occupy positions much below the level of the Cretaceous plains, being in one of the three following positions* :—

(*a*) Slightly elevated above the Tertiary peneplain.

(*b*) On the Tertiary plain.

(*c*) Occupying basalt-filled valleys excavated in the elevated Tertiary plain.

They would then naturally fall into late or middle Tertiary streams, and Post-Pliocene streams.

In this connection, attention must again be drawn to the fact that in the absence of palæontological criteria of the ages of the high levels, deductions can only be made as to their position in time from the evidence yielded by a knowledge of the relative amounts of material lost to the various plateaus in the formation of successive plains by subaerial agencies.

The photographs illustrating typical scenery in the north-eastern portion of the State accompanying this report were secured by the writer during his observations.

Explanation of Terms.

Base-level of erosion.—The surface below which the forces of erosion are ineffective. Local significations may be applied to the term. Thus a lake surface becomes a base-level of corrasion or erosion for the streams emptying into the same. The great level, however, to which all surfaces approximate, if unaffected by deformation, is the surface of the sea.

A cycle implies the period during which some great topographical change is effected in a landscape. Cycles of erosion, for instance, involve the time occupied in the reduction of a region of relief to the peneplain or base-level stage. Cycles of elevation, depression, deposition, warping, and other activities are terms also in use among topographers. Cycles of uplift, depression, or erosion are often interrupted by oscillations of level; these, according to their importance, may be designated epicycles or vibrations† of such movements. The greater "facts of form," however, observable in a region give the name to the cycle. For example, a cycle of depression may be interrupted by minor uplifts or depressions, thereby diminishing or accentuating the surface relief; nevertheless, the larger topographic features being practically unaltered, the fact remains that the cycle, broadly considered, is one of subsidence.

Erosion is a complex process, involving the threefold action of weathering, transportation, and corrasion. The effect of erosion is to reduce raised topography to base-level, and to aggrade contiguous offshore areas.

---

* A possible exception is an instance cited by Prof. David as occurring on the Mole Table-land. Memoirs Geol. Survey N.S. Wales, Geol. I, p. 71.

† F. P. Gulliver.—Shore-line Topography. Proc. Am. Acad. Arts and Sci., 1899, xxxiv, pp. 152-258.

Weathering brings about rock decay; *transportation* the removal of the products of decay; and *corrasion* the deepening and widening of stream channels by the forces of abrasion and solution. Many variables control erosion, such as amount of rainfall, topographic relief, and denseness of vegetation.

Geomorphology treats of the descriptions and correlation of surfaces, while *geomorphogeny* treats of the origin of such land surfaces.

After vertical corrasion has effected the cutting up of a plateau into mountain blocks, lateral corrasion seeks to further isolate the detached portions. These are known as *relict mountains, mountains of circumdenudation*, or *residuals*. Large flat-topped masses are known as *mesas*, smaller ones *buttes*. Residuals which form more or less continuous mountain masses are called *unakas*, while isolated mountains are known as *monadnocks*.

Streams following the original slope of an upheaved surface are known as *consequent* rivers. Tributaries of these consequent streams which follow anticlinal structure, line of strike of strata, and some other structural features become *subsequent* streams. *Insequent* streams are determined by accidents of surface, while *obsequent* streams originate in stream piracy. Strong subsequent streams, by rapidly incising themselves in a plateau, soon approximate to base-level and thus capture the headwaters of weaker consequent streams. The portion diverted into the subsequent stream is reversed and known as an *obsequent* stream. Rivers discovering highly inclined strata after sinking through a horizontally-bedded rock capping, persist for a considerable period in the courses imposed on them by the surface and structure of the overlying unconformable strata. Such are known as *antecedent* or *super-imposed* streams. An adjustment of streams to the structure of the lower-lying rocks results only after the removal of the unconformable cap. *Betrunked* streams arise from the submergence of lower river courses. *Rias* are examples of submerged subaerially formed valleys.

Stream Development.

The history of a land surface after elevation is largely bound up in the development of its streams, since the sequential forms represent, in one case, those land-blocks left standing in the interstream areas, and in the other case those like flood plains due to the aggrading action of the streams. Many variables control the development of watercourses. Erosion is a convenient term for the totality of the agencies which tend to remove an elevated area into the sea. The forces of erosion admit of grouping under three headings, viz, weathering, corrasion, and transportation.

Weathering is both chemical and mechanical in action. Among the mechanical agents may be mentioned wide and frequent variations in temperature, which make for wholesale rock destruction. Magnificent examples of frost action are apparent

on rock slopes at high altitudes, where wide masks of talus gather round the cliffs. Nor must the influence of *deflation* be underestimated. In arid regions the friction caused by sand blasts is very effective in the reduction of land surfaces. Rain and hail also tend to break up the more incoherent masses of rock.

Earthquakes, volcanic action, landslips, and the silent but wondrous forces which induce joint systems in rocks, all make for the degradation of land surfaces. Master and other joints in turn become solution and friction planes, thus promoting rock-decay in a remarkable manner.

Solution is a powerful factor in rock decay or weathering. Rain water percolating through incoherent rocks and along joints becomes more or less saturated with various acids. Its capacity for work is thereby greatly enhanced. Limestones especially fall an easy prey to its solvent properties; while changes are induced in others so as to assist the agents of mechanical weathering. High temperatures and great precipitation are conducive to rapid chemical changes in the earth's crust, the popular expression for which is weathering, or "rock decay."

The observed order of events in stream transportation furnishes impressive lessons to the student of topographic forms. Coefficients of value in the removal of the products of rock fracture and decay are declivity, volume of water, and degree of comminution to which the stream load has been reduced.

Declivity and ability to transport as regards stream action are not "related by a simple ratio." Increased declivity implies acceleration in speed, and by experiment—the action of friction being reduced to a minimum in the trials—the transporting power of a stream varies as the sixth power of the velocity. Thus, doubling the velocity increases the moving power sixty-four fold; trebling it gives seven hundred and twenty-nine times the transporting power; while a quadrupling of the velocity enables the stream to perform four thousand and ninety-six times its former work.

Increase in volume also, by accelerating the speed, greatly increases the efficiency of transportation. A simple illustration of the fact that increase in the volume of water induces speed is furnished by an examination of rivers in flood-time, where the filling of the channels is accompanied by impetuosity of current. Bearing in mind the wonderful divergence from a simple ratio of increase in speed and capability of transportation, the work accomplished by high grade streams during periods of flood admits of easy interpretation. In the deeply dissected mountain masses of eastern New England, angular blocks of rock forty or fifty tons in weight have been observed to move several chains down the graded watercourses, while along the mountain tracts of the same area the crash and rattle of boulders dashed against each other in time of flood may be heard above the roar of the escaping waters.

The degree of comminution to which the transported material has been reduced is also an important consideration in transportation. Increase of ratio of surface to volume as regards solids occurs when the particles are reduced in size. This condition of affairs is accompanied by increased facility of transporting power for the streams. Thus sand particles are moved more easily along a watercourse than pebbles, and these in turn than boulders.

Rock fragments hurried along by moving water (or wind) exert an abrading effect on the sides and bottoms of watercourses. Incisions made by the streams are thus deepened and broadened in elevated areas. Chemical solution by acidulated waters also promotes land degradation. To this two-fold action of the streams, viz., *abrasion* and *solution*, the term *corrasion* has been applied. A proper conception of the term "corrasion" is impossible to those who are acquainted with regions of mild relief only. Here the forces of abrasion are reduced almost to a minimum. The streams lack the impetuousness of youth, the great decrease in declivity does not admit of rocks being borne along in suspension to vigorously assault the precipices which beset the courses of the streams. Students of regions of considerable uplift will, however, see evidence of action which has taken place much as follows. We may conceive of a slope of small angular value which has carried a land surface from sea-level to a considerel height in a distance of many miles. Rain falling on this gently-inclined area gathers into rills and streams which take the shortest possible route to the sea. *Contour*, or *consequent* streams originate thus. Abrasion and solution allow the streams to establish themselves upon the table-land in shallow valleys. If the strata be horizontally bedded and of hard nature, narrow trenches will be developed in them by the corrading waters at extremely slow rates; while on the other hand, if the rocks be soft or of varying hardness and highly inclined, broad, deep valleys will quickly be the expression of the stream action. After penetrating a hard horizontal layer, the corrading stream may discover an underlying soft mass. Instantly the deep, narrow cañon which expressed the strength of the incising stream in the indurated beds expands into broad valley form as the soft rocks weather rapidly and undermine the masses above. Waterfalls accompany the deeper trenching of the plateau, and indicate the earlier chapters in the dissection of the uplands. After a time the waterfall stage vanishes, the plateau is well dissected, and the grading of the watercourse passes through some of its earlier phases. The valleys are excessively deep, but numerous small alluvial flats accompany the fortunes of the streams, while the whole mass of the interconsequent stream areas has been trenched and retrenched by narrow cañons comparable in depth with the main channel. Thus a vast amount of surface becomes subject to the attacks of weathering, transportation, and corrasion. This, the action of vertical corrasion, is a comparatively rapid process. The deflection of streams from rectilinear courses brings about the attack of the cliffs bordering the cañons as the water swings first to one side and then the other of its channel. This deviation from a straight

channel is in a great measure due to decrease in declivity, which involves the diminished competence of gravity to maintain a straight course for the stream, and the increased efficiency of obstacles to turn it from its path. The deflection, however, being brought about, and the enclosing cliffs attacked during the stream oscillations from side to side of its valley, the talus showered down from the precipitous slopes is rapidly disposed of, weaknesses of structure are utilised, the cliffs are undermined and recessed until, by a combination of circumstances, the stream migrates to the other side of its valley. Along the mountain tracks of the New England streams the experienced observer can locate from afar the exact position of the stream. Amongst the hosts of spurs which advance into the deep valleys and overlap each other for great distances, huge slate and granite cliffs may be seen from several hundred to a thousand feet in height. These mark the spots at which the streams are actively engaged in undermining the spurs. On the other side of the watercourse the spurs reach down long grassy slopes towards narrow belts of river flats. The operation of well-ordered processes having withdrawn the stream from the cliff face, it proceeds to oscillate across its narrow valley, the sandy flat on which the grassy spur opposite the cliff abuts is swept away, the waste sheets which simplified the ascent of the spurs are in turn removed, the underlying rocks are exposed, and the undercutting process and cliff-forming is renewed, this time, however, on the opposite side of the stream. Meanwhile, the recessed cliff, removed now from the direct onslaught of the river, still continues to shower down *débris* which, accumulating, mounts higher and higher, and threatens to mask the individuality of the cliff in its advance. Screes are thus formed, known in New England as "Wallaby slides." Aggradation, or deposition of material by the stream, now ensues for this side of the valley, sandy and gravel flats being formed. These then—alluvial flats, wallaby slides, and modified cliffs—succeed to the precipice of corrasion when the stream swings to the other side of its valley.

Repeated oscillations occur, the amplitude of swing increasing each time, and the valleys become broadened from V-shaped to U-shaped forms in section.

This process, whereby extension in breadth succeeds to an approximation to base-level of streams by vertical corrasion, is known as lateral corrasion. The latter process is much slower than the first-named. By this method torrent courses give place to valley tracks, which lower down stream have already, if the strata be soft in nature, opened out into great flood plains, across which the river slowly meanders, swinging from one side of its wide valley to the other, the hills enclosing the valleys being attacked alternately by the forces of lateral corrasion. A fresh adjustment to base-level accompanies each journey of the river across its flood plain. The forces determining these enormous migrations of the stream along its lower reaches are mostly those arising from obstacles barring the stream-course when declivity has been reduced to a minimum.

The final stages of base-levelling are dependent more upon solution than upon abrasive action, and must occupy a vast period of time, so slowly acting are the processes involved.

The reduction of a plateau of high relief to a peneplain is by some writers held to consume no longer a time than one of mild relief.

Conceive of two regions dome-shaped and sloping gradually from central ridges four thousand and five hundred feet respectively in height to sea-level in a distance, say, of a hundred miles. We will also suppose each area to have the same general rainfall. By the time head-water corrasion had acted so as to incise cañons three thousand five hundred feet deep in the centre of the higher dome, an even grade would, in the ordinary condition of things, have been imposed on the river channel, and the slopes of the main watercourses would at this stage be approximately that of the smaller plateau, which slopes gradually from five hundred feet above sea-level to that same base. Thus, subsequently to the cañons having been cut down in the more elevated area to the five hundred feet level at their head waters, there is yet underfoot at this level a volume exactly equal to that of the smaller plateau. In addition to this volume of material, there yet remain the great residuals of the interstream areas. At this stage declivity and volume of water are equal for both regions, and the cañons of the higher region cannot now incise themselves more rapidly into the lower portions than the consequent streams of the region of mild relief. Thus it appears that, all other things being equal, the reduction of a region of high relief takes a much longer period to accomplish than that of a more lowly one.

The influence of rock structure on stream development is very important, and in the mature stages of valley formation an adjustment of streams to structure takes place. The weaker structures vanish early in the cycle of erosion. Downfolded layers generally in maturity form the hills, while the streams occupy the anticlines. Rocks such as quartzites, dense sandstones, and indurated slates often form high hills on a peneplain when masses of ordinary slates and jointed granites have suffered removal at the hands of the agents of erosion. By the unequal erosion of early-established divides, rivers materially modify their courses, giving rise to subsequent, insequent and obsequent streams. Superimposed rivers also owe their existence to unconformability of strata.

The term "base-level"* has been used in the preceding pages with the significance assigned to it by American writers. Stream corrasion, mechanically considered, is limited in vertical extent by a plane coincident with that of the surface of the water body into which it flows. This plane is defined as the "base-level" for the streams of the area considered at any time. Lake surfaces form local base-levels, but the great base-level to which all land surfaces tend to be reduced is the surface

*For a fuller description of "base-level," see the various works of Powell, Dutton, Davis, Gulliver, and others enumerated on p. 151.

of the sea. The final steps in the reduction of a region of relief to base-level are necessarily extremely slow. The efficiency of vertical corrasion becomes almost negligible, and lateral corrasion accomplishes most of the task with gradually diminishing competence. The final touches, however, are given by chemical corrasion.

Perfect plains of erosion are of extremely rare occurrence, owing to the time occupied in the final stages, deformation generally setting in before the cycle of denudation is complete. Surfaces of incomplete planation, however, frequently occur, and are known as peneplains. Isolated mountains are frequently found rising abruptly above the general level of these gradation surfaces.

"Base-levels" must be understood as fixed surfaces, incapable of deformation.* Thus it is not advisable to speak of the upheaval of a base-level of erosion. What is understood is that a plain approximately developed to base-level for the region considered has undergone elevation.

These notes on stream development are mostly a *résumé* of the views held by Dutton, Powell, Davis, Russell, Ruetimeyer, and other topographers.†

The salient features of the Plateau and associated Coastal Area.

The New England plateau proper extends from the neighbourhood of Nundle, in the south, to the Queensland Border, on the north, a distance exceeding one hundred and fifty miles. It might, however, rationally be made to embrace the high plateau and isolated flat-topped mountain masses separating the Manning and Hunter headwaters, and known as the Tomalla, Timor, Gumi, Barrington, and Dungog Tops, These, in fact, are coextensive with the general level of higher New England. The length would thus be about two hundred miles. The eastern edge of the plateau is

---

* F. P. Gulliver.—Shore-line Topography.

† The following works, dealing with physiographic questions, may, with advantage, be consulted :—

CROSS, WHITMAN.—The Laccolitic Mountain Groups of Colorado, Utah, and Arizona. Ann. Rept. U.S. Geol. Survey, 1892-93, pt. 2, pp. 157-241.

DAVIS, W. M.—The Development of certain English Rivers. Geogr. Journ , 1895, v, No. 2, pp.

———— Plains of Marine and subaerial Denudation. Bull. Geol. Soc. Am., 1896, VII, pp. 377-398.

———— The Triassic Formation of Connecticut. Ann. Rept. Geol. Survey U.S., 1896-97, XVIII, pt. 2, pp. 1-192, pls.

DILLER, J. S.—Tertiary Revolution in the Topography of the Pacific Coast. Ann. Rept. U.S. Geol. Survey, 1892-93, XIV, pt. 2, pp. 397-434, pls. and maps.

DUTTON, C. E.—Tertiary History of the Grand Cañon District. U.S. Geol. Survey, Mon. I, 1882. With Atlas.

GEIKIE, A.—The Scenery of Scotland.

GILBERT, G. K.—Geology of the Henry Mountains.

GULLIVER, F. P.—Shore-line Topography. Procs. Am. Acad. Arts and Sci., 1899, XXXIV, pp. 152-258.

———— Cuspate Forelands. Bull. Geol. Soc. Am., 1896 VII, pp. 399-422, pl. 18.

HAYES, C. W.—Physiography of the Chattanooga District, in Tennessee, Georgia, and Alabama. Ann. Rept. U.S. Geol. Survey, 1897-98, XIX, pt. 2, pp. 1-58, maps.

KEITH, A.—Geology of the Catoctin Belt. Ann. Rept. U.S. Geol. Survey, 1892-93, XIV, pt. 2, pp. 285-395, pls and maps.

POWELL, J. M.—Geology of the Uinta Mountains.

RUSSELL, I.—River Development. (8vo., London, 1898.)

SHALER, N. S.—The Geological History of Harbours. Ann. Rept. U.S. Geol. Survey, 1891-92, XIII, pt. 2, pp. 93-209, maps and pls.

bordered by deep gulches, waterfalls, and inaccessible precipices. Nowendoc Tomalla, Glen Rock, Yarras, Winterbourne, Guy Fawkes, Hillgrove, Marengo, Bald Nob, Glen Elgin, Boonoo Boonoo, Undercliffe, and Wilson's Downfall mark some of the points along this margin. Eastward of these points long peninsulas advance from the general level for many miles, all rising to the same height as the table-land, and accompanied by profound ravines. Great flat-topped blocks occupy still more easterly, and also inter-peninsular, positions, and so closely set together as to suggest the idea of present coextension with the plateau from a short distance. A closer study shows them to be isolated therefrom by deep V-shaped gorges, as much as three thousand five hundred feet deep in places.

The edge of the unbroken upland would, therefore, form an excessively tortuous line.

To the west the boundaries are not so pronounced as those on the east. Deep gullies are common, but profound precipices and waterfalls are rare.

The accompanying sketch map represents approximately the general extent of the plateau proper. (Pl. XXXVIII.)

New England is characterised by its terraced appearance. Two of the levels are more pronounced than the others, and admit of a division into Upper and Lower New England. This statement must be understood to be applicable to the plateau proper only.

Lower New England has a general height of three thousand three hundred feet the area being characterised by gently undulating surfaces, dotted over with numerous small towns. Tenterfield, Deepwater, Glen Innes, Emmaville, Tingha, Armidale, Hillgrove, Uralla, and Walcha occupy the centres of extensive expanses of country, over which numerous sluggish streams flow in shallow basins. Contorted slates and granites of various Palæozoic ages compose the general flat of the lower uplands, and by reason of their auriferous nature provide a living for numerous miners. Alluvial and reef tin occurs also in abundance. Rock surface and dip are not at all coincident at this level, the slate dips being bevelled off by erosion so as to end abruptly against the land surface. Basaltic-capped knobs are of frequent occurrence on these peneplains, the underlying portions consisting of thick masses of auriferous gravel. By contrasting these old stream deposits with those of the present watercourses draining contiguous areas, marked differences in the laws governing the two periods of stream development become at once evident. The older courses are generally at a slightly higher level than the plateau surface, the river *débris* is of great thickness, consisting usually of a base of well-rounded pebbles, many feet in thickness, auriferous in character, and capped by alternating belts of sand, clay, and earthy lignite.

The present stream channels are characterised by their lack of water and load.

It will be shown later that these basalt-capped drifts, known as "deep leads," tell of vastly dissimilar conditions, climatic and topographical, obtaining at the time of their deposition to those now existing in the same localities.

This level is divided into two almost distinct regions by a high basalt plain between Armidale and Glen Innes. The two are, however, co-extensive to the west by way of Booroolong. The southern example may, perhaps, be named the Sandon peneplain, coinciding as it does with the Sandon Gold-field. Walcha, Uralla, Armidale, and Hillgrove are situated thereon. The northern half, famed for its alluvial tin, may, perhaps, be named the Stannifer peneplain. (Pl. XXXVIII). Emmaville, Tenterfield, Tingha, and Glen Innes are the chief towns.

Higher New England presents marked variations in structure and appearance. In the neighbourhood of Tenterfield the three thousand feet level is almost completely encircled by flat-topped granite mountains. Here and there the lower plateau is contracted, and winds tortuously through the ranges before effecting a connection with another plain at the same level. Only to the east does it keep on with little interruption. The higher land admits of separation into two terraces, one about the same extent as the three thousand feet level, and occupying a plane one thousand feet higher, the other indicated by numerous peaks, rarely flat-topped. Those with horizontal surfaces rise about five hundred feet above this four thousand feet level. The peaked forms which are more common are still higher. Conspicuous among these higher points are Ballandean, Bald Rock, Mount Mackenzie (flat), Mount Spiriby, The Magistrate, and Capoompeta. Repeated granitic intrusions characterise the lower level of erosion (three thousand feet). Here fine-grained biotite granites and felspar porphyries are intruded in a marked manner by coarse acid types of granites. The residual mountains consist for the most part of the intruding coarse granites and magnificent examples of granite porphyry. Of the two types, the fine-grained rocks appear to be the harder, but joints and weak structures arising from repeated intrusions are extremely common.

We have, then, in this northern division of New England signs of at least three levels, viz., at four thousand five hundred, four thousand, and three thousand feet above sea-level. The oldest and highest may be known as the Bolivia Plain, since the great mountains of Bolivia, Capoompeta, Spiriby, and The Magistrate represent residuals of this level.*

The four thousand feet level may be called the Mole peneplain, since the Mole table-land represents a portion of this plain. It must be remembered, however, that the levels here have a pronounced slope to the west, so that where the Mole River junctions with the Dumaresq, the leve is reduced to about three thousand feet. As mentioned before, the three thousand feet level at Tenterfield belongs to the Stannifer Plain.

* These, however, seem separable into two distinct levels, viz., four thousand five hundred feet and five thousand feet.

In the neighbourhood of Deepwater, Dundee, and eastwards of these localities the Mole Plain sinks into insignificance when compared with the enormous development of the Stannifer level. Eastwards the plateau rises almost to the four thousand feet level, its co-extension with the three thousand feet level being, however, well preserved.

Residuals of the Bolivia plateau are common.

Granite is the chief rock constituent of these masses. Softer slate and small patches of intrusive granite form the greater portion of the great surface of the Stannifer plain in this district.

Glen Innes and Armidale represent the centres respectively of enormous extensions of the Stannifer and Sandon peneplains. Eastwards of both these towns the plains stretch away to the limit of vision. Especially in the case of the Sandon Plain is its great development marked eastwards and south of Hillgrove. Profound but narrow gorges render this district almost impassable; this, however, is not noticeable from the point of view of the small undulations of the plateau, the effect being that of a far-reaching level uninterrupted by mountains or gorges. The wonderful development of the Sandon Plain in the Armidale district is mostly due to the relative weakness of a mass of vertical slates forming the bulk of the rocks.

The intermediate areas between Glen Innes and Armidale are occupied by high basaltic levels, two of which stand conspicuously, viz., the five thousand to five thousand two hundred, and the four thousand three hundred to four thousand five hundred feet level. To this four thousand five hundred feet level may be given the name of the Guyra Plain, from its great extent in that locality. (Pl. XXXV, fig. 2.) The flat appearance of this plain is most characteristic. Viewed from the Sandon and Stannifer levels, it extends as an unbroken ramp east and west to the limit of the vision. Magnificent views of it are afforded from Stonehenge, Glen Innes, and Waterloo on the north, and from Armidale on the south. Above it are scattered numerous flat-topped and cone-shaped masses, rising to heights of five thousand and five thousand two hundred feet above sea-level. These are also basaltic in character, and show a regular succession of basic rock types during their ascents. Mount Mitchell, Ben Lomond, Chandler's Peak, and Big Duval are among these highest points.

Guy Fawkes, lying forty miles east by north of Armidale, is basaltic in character, and possesses a terraced appearance. The general height is four thousand five hundred feet, but residuals with subhorizontal summits rise to the five thousand feet level. To the west the plateau is separated from the Sandon Plain by the Snowy Range, composed of an irregularly shaped mass of granite, reaching an extreme height of five thousand two hundred feet in the Round Mountain. Against the irregular sides of these peaks the basalt ends abruptly as though filling

a depression in the country and rising to a general level. This level corresponds doubtless with the Guyra Plain, and the Snowy Mountains represent residuals of the Bolivia plateau.

Seen from such peaks as Spiriby, Capoompeta, Ballandean, Mackenzie, Round Mountain, and Ben Lomond, the three distinct levels of the Stannifer, Mole, and Bolivia plains (as also the Guyra) are most characteristic, the two lower being especially well preserved while the residuals of the Bolivia upland are mostly conical—rarely flat-topped. The relation between the Guyra and Mole plains will be hereafter described.

Coming south the higher levels obtain the ascendancy, and the three thousand three hundred feet level is much contracted. In the neighbourhood of Walcha the uplands are chiefly swampy basaltic areas rising from four thousand to four thousand five hundred feet, and containing still higher isolated basaltic points.

In the Hunter and Manning Rivers basins, the higher levels, two in number, are principally basaltic. Tomalla, Timor and Gummi Tops, as also Callaghan's Swamp and other flat areas, appear to represent extensions of the Guyra and Ben Lomond levels, being from four thousand five hundred to five thousand feet high. Barrington Tops, about five thousand feet in height, are composed of granite. Mount Oxley and other flat-topped peaks lying to the west of the main Hunter valley are flat-topped basalt masses rising from another high level basaltic plateau.

With the exception of the isolated masses now forming the highest points of New England, it will be found generally, as far as northern portions of the area under discussion are concerned, that the basalt forms but a veneer over Palæozoic slates and acid igneous rocks. In ascending the higher levels from Armidale the underlying granites and slates crop out everywhere as high up as the four thousand two hundred feet level. In the Guyra Lagoon (Pl. XXXVI, fig. 4), four thousand three hundred and thirty feet above sea-level, and at various points over four thousand feet above the same base along the Guyra-Oban Lyndhurst, Black Mountain, Tingha, Llangothlin, and Kookabookra roads, granite, quartz, and slate are met with. In the Glen Innes-Inverell, Glen Innes-Bald Nob, and Armidale-Uralla districts this mere veneering of basalt is well seen. Along the lower level the basic lavas are mostly confined to the old watercourses.

At Guy Fawkes, Mount Lindsay, Ben Lomond, and other localities, however, enormously thick masses of columnar basalt are exposed in natural section.

The upper levels, especially when basaltic in origin, are characterised by large swampy areas. Among these may be mentioned Callaghan's Swamps, the marshes of the mountains between the Hunter and Manning Rivers, the Guy Fawkes swamps, the Guyra and Llangothlin lagoons, and the marshy tracts of the mountains east of Deepwater. The three thousand three hundred feet level is more undulating in character, and supports but few swamps or marshy tracts.

One of the first facts impressed upon the observer when comparing the various levels is the variations of slope presented when descending the 4,500 and 4,000 feet levels to the Sandon and Stannifer plains, and the slopes of the eastern falls of the latter. No waterfalls mark the descent from the highest levels, the rivers present old-age features, while enormous cascades and falls characterise the descent of the 3,300 feet level to the present coastal rivers.

The residuals of the Mole peneplain slope sympathetically with the Sandon and Stannifer plains, as these show decrease in height east and west of the plateau proper. Thus, at Tingha, the Stannifer plain has sunk to 2,850 feet. Flat-topped residuals occur on it about 1,000 feet higher. But especially well is this illustrated in a traverse west from Tenterfield and Bolivia, where the three levels are seen to decrease evenly. With respect to the lower one, the following heights taken at various points indicate the character of the elevation forming the table-land :— Wilson's Downfall, 3,000 feet; Tenterfield, 2,900 feet; Deepwater, 3,200 feet; Glen Innes, 3,500 feet; Armidale, 3,300 feet; Uralla, 3,300 feet; Walcha, 3,400 feet. These occupy the central portions of the plateau. The southern half of New England has its eastern border mostly in the higher basaltic levels.

To the west the general level has fallen to 2,800 feet or 2,900 feet at Tingha, 2,700 feet near Inverell, and 2,900 feet at Emmaville.

The heights of outstanding portions of the 3,300 feet level will be given when discussing the characteristics of the eastern and western falls of the plateau, and from these measurements the general slope of the plateaus before degradation had got well under way, may be arrived at.

Plateaus once coextensive with New England lower level are the Darling Downs, the Blue Mountains, the Illawarra Mountains, and Monaro.

As the Darling Downs are approached the level sinks to 2,650 feet at Stanthorpe, and to less than 2,000 at Toowoomba, capital of the Downs.

The Blue Mountains, superficially considered, consist mostly of Triassic sandstone. The surface is undulating, but continuous. Summit levels are—Sydney, 350 feet; Port Hacking (15 miles south of Sydney), 700 feet; Clifton, 1,200 feet; Bulli Pass, 1,340 feet; Kiama (50 miles south), 2,000 feet; Moss Vale, 2,200 feet; Springwood (40 miles west), 1,200 feet; Blackheath (60 miles west), 3,500 feet; Wiseman's Ferry, 800 feet; Peat's Ferry (30 miles north), 700 feet, and Capertee 120 miles north-west), 2,600 feet.

Here, then, in the well-nigh horizontally-bedded Trias system the tale of deformation is easily read. With the excessively altered Palæozoic rocks of the northern plateau the problem becomes complicated, especially as degradation proceeds. In the latter case the criteria mainly to be depended on are the co-extension of levels or slopes for the table-land itself, and the probably continuance

of slopes east and west as revealed by a study of isolated blocks of surviving ridges. Structure here is an exceedingly complicated problem, and would require years of patient mapping and keen geological insight for its elucidation. The table-land itself consists mostly of slates, contemporaneous and intrusive rhyolites and porphyries, and plutonic acid intrusives on a gigantic scale. The slates themselves are remarkably similar, and lack distinctive conglomerates, sandstones, and limestones by which to understand the folds into which the strata have been thrown. The Palæozoic foldings might, even with this similarity of strata, be fairly easily made out were it not for the latter plutonic intrusions. Into the masses of folded slate great bosses, tongues and laccolites (?) of granite, quartz diorite, quartz and felspar porphyries have been thrust. The action of these intrusive masses, widely separated in point of time, has been to destroy in great measure the record of the earlier earth movements told by the rock dips. So frequent are the acid bosses that in many places the dips of the contorted slate might equally be assigned to the action of the granites as to the general earth movements. The masking of the Palæozoic complex by Tertiary basalts is also pronounced. Probably only an examination of the western and eastern aspects of the plateau will reveal its true structure. Here, although granites are frequently present, their mass is insignificant compared with that of the stratified rocks and extensive areas exist over which their influence is negligible. The immense masses of slate along the Upper Macleay show a prevailing strike, with signs of large folds as at Walcha.

At Rivertree, Drake, Tooloom, and Boorook the Permo-Carboniferous conglomerates, slates, claystones, and rhyolites could easily be studied and their structure understood, as the action of the later granites can here be differentiated from successive slight earth movements.

Sections west of the plateau could easily be obtained for the Palæozoic strata between Narrabri and Inverell, Gunnedah and Uralla, Werris Creek and Moonbi.

Possibly one of the finest sections across the plateau could be obtained between Merriwa, Scone, Moonan Brook, Tomalla, Glen Ward, Copeland, Gloucester, and Taree. Here the action of the granite on the strata—mainly Carboniferous—could be neglected. The Hunter River reveals a series of highly folded rocks, while several distinctive bands occur, such as conglomerates and limestones, whose presence would simplify studies in folding and faulting.

The Eastern Fall of the Plateau.

The eastern fall of New England is remarkable by reason of its extreme ruggedness and wealth of topographic forms. Admittedly rough as the western fall is, it sinks into insignificance in this respect when compared with the Pacific slope. From Mount Lindsay, in the north, to the Dungog Tops, in the south, a series of

gorges, with tumultuous profiles, present a bar to closer settlement, and almost isolate the plateau from the coastal inhabitants. Yet so great is the variety of relief, that the mountain tracks of no two coastal rivers could possibly be confused by the observant. The Tweed, Richmond, Clarence, Bellinger, Macleay, Manning, Karuah, and Hunter Rivers valleys can all be easily distinguished.

For years the upland remained inaccessible from the coast, owing to the long lines of granite and slate precipices which formed the heads of the cañons receiving the drainage of the upper areas. Yet, in the central portions of the upper levels, a stranger to its characteristic features might easily be mistaken as to the nature of the eastern fall. Riding along the three thousand three hundred feet level eastwards of the Great Northern Railway, the individuality of the table-land appears to be unbroken. Its general flat rises here and there into mountains of moderate relief. No signs of plateau dissection are visible in the distance; yet, but a few miles ahead, profound cañons may have almost completely cut up the apparently continuous plain into unapproachable masses. Thus, along the upper Macleay, in the neighbourhood of Tia, Apsley, Wooloomumbi, or Salisbury Rivers, the mountains rising above the Sandon plateau may, at a distance of several miles, appear easily approachable, while, in reality, a detour of thirty or forty miles may have to be made to arrive at their bases. From the summits of such peaks as the Blue Mountain and the Round Mountain, where the observer is well above the lower table-land, the true nature of the country may, however, be taken in at a glance.

Characteristically broad, shallow, and sluggish streams, having every appearance of extreme old age, except for the small incisions developed by them in the plain, traverse the plateau for distances varying from ten to thirty-five miles, then precipitate themselves over great ledges from three hundred to a thousand feet in depth. Thence, as torrent tracks, their courses are continued through V-shaped gorges several thousands of feet deep. Beyond this, the table-land has suffered greater isolation, yet, even so, viewed from a short distance, the blocks still appear coextensive. At a certain point, which, meridionally considered, is not constant, the peneplain dips towards the sea, a gradual decrease, subject, however, to deformation in height of the hills, takes place as the coast is approached. The V-shaped valleys give place to broad channels, U-shaped in section (Pl. XXXII, fig. 2.), the mesas disappear, and are succeeded by a plexus of razorbacked mountains and spurs. Above all these higher points occur. As the coast is neared, the mountains in the neighbourhood of the larger river-mouths become very isolated, the intervening areas being characteristically undulating, the rivers broaden out into plain tracks, while long lines of coastal flats separate these in turn from the sea. In the interstream areas of the coastal strip the mountains may advance long wooded spurs into the sea. Beautiful lakes and lagoons are enclosed by these embayed mountains. In many places these mountainous spurs and ridges attain a height of five

hundred to one thousand feet near the shore, while isolated peaks attain still greater elevations. Were, however, the valleys to be filled up, the Sandon and Stannifer plains would be found to have, generally considered, a steady decrease in slope to the sea. Deformation, however, has produced local variations in surface slope, and faults accompanying the deformation still further modify the topography. Above this continuous slope would be discovered flat-topped mountains, with still higher points rising from their shoulders or the lower levels. These would consist of Palæozoic rocks. Huge dome-shaped masses of Tertiary basalt would be frequent, and tend much to destroy the idea of a series of gradation surfaces.

Along all of the mountain tracks of these eastern streams, and especially where large flows of basalt cap the ranges, the densest jungles and mighty forests obtain. (Pl. XXXVII, fig. 2.) Magnificent blackbutts, blue-gums, flood-gums, ironbarks, tallow-woods, box-trees, red cedar, Richmond River pines, and other valuable timber trees range side by side over thousands of square miles, and frequently attain a height exceeding two hundred or two hundred and fifty feet.

Closer settlement has been proposed for these mountain fastnesses; but, it is doubtful if this will ever be brought about. Its wealth consists in its timber, and, as forest reserves, the State will derive great future revenues from these at present almost impassable gulches. Gold, silver, and copper are also found more or less plentifully in these regions. But at most it will only support a scattered population, as similar regions in Europe and America—areas of dense populations—are almost uninhabited save by pastoralists, miners, and timber getters.

Adverting, however, to the main question, viz., the relief of the eastern fall we will find a considerable variation in the appearance of the mountain, valley, and plain tracks from north to south. These variations are the expression, as will be shown hereafter, of differential movement, structure, and rock composition, and unequal volcanic activity.

North of Tenterfield the Macpherson Range forms the border between Queensland and New South Wales. Here the rocks consist of granites, Palæozoic slates, Trias-Jura sandstones, coal measures, and lavas. Tertiary volcanism has capped these with great thicknesses of columnar basalt. The residuals of the one-time continuous mass are now represented by mesas, aiguilles, and dome-shaped mountains. Individuals among these comprise some of the most imposing mountains of the State. Mount Lindsay is an example of a mesa, about four thousand five hundred feet in height—a granite base capped by columnar basalts a thousand feet in thickness—and presenting inacessible precipices in all directions. Broad valleys excavated in the soft Triassic strata separate it from other peaks. Mount Wilson is a replica of Lindsay on a smaller scale. Mount Warning furnishes an example of an aiguille (Pl. XXXVII, fig. 2) isolated from the main range by broad valleys, while the Obelisks are dome-shaped trachytic necks.

East of Tenterfield the gorges are very deep, but less pronounced than in regions farther south, the torrent stage in stream development is rapidly passed, and broad valley tracks are characteristic.

A little to the south one reaches the country drained by the South Clarence streams. Here the Mole Plain, four thousand feet in height, presents a series of almost inaccessible precipices to the creeks flowing into the main stream. The gorges, among which may be cited the Cooraldooral, Dundahra, and Coombadjha, attain a depth of as much as three thousand feet. Here, as in the area east of Tenterfield, the main level of the plateau may be traced for many miles across the ravines by reason of the flat-topped mesas bordering the valleys on either side. The large subsequent streams run north and south, giving great length but little breadth to the isolated, or nearly isolated, mountain masses. This great development of subsequent drainage was accomplished at the expense of smaller consequent streams.

Between Armidale and the coast the traveller passes over the Sandon Plain (Pl. XXXII, fig. 1) by way of Hillgrove and Wooloomumbi, skirting great cañons the while without being aware necessarily of their proximity. Thence for miles he proceeds over areas of alternating igneous rocks and bevelled slate until the great winding granite mass of the Snowy Mountains stretches across the line of march. Rising to a height of five thousand two hundred feet in the Round Mountain, the range is visible for fifty miles in every direction from the plateaus, while to the east it sentinels the horizon for a hundred miles. Its skyline bristles with huge tors arranged in groups strikingly suggestive of weird architectural effects. Locally they are known as the Cathedral Rocks. Immediately the range is crossed, the basaltic plateau of Guy Fawkes is seen stretching away seawards in the form of a terraced peninsula rising from four thousand five hundred feet at the point where the lava flood welled round the granite slopes to five thousand two hundred feet on its eastern margin. A few miles' ride eastward across a flat leads to a gradual rise among basalt blocks weathering out into gigantic bombs. Thence a final skirmish through a messmate forest and a "black scrub" brings the rider to a point where the forest suddenly disappears. The path ends, and the traveller stands on the edge of a mighty precipice affording a panoramic view extending for a hundred miles to the north, east, and south. The plateau has ended abruptly, and fallen away almost five thousand feet in one bound. In the rear the lava sheets pass in terraces and gentle undulations to the granite slopes of the Snowies, ahead the country appears to have been cut off as with a knife from the uplands and dropped to an entirely lower level. One stands on the edge of a great parapet, black in colour, stretching from left to right to the limit of vision, and about fifteen hundred feet in height. An almost insurmountable barrier is thus presented to communication with the valley below. Not straight, but sweeping with broad curves into great embayments, the lines of the parapet possess grace without

suffering in strength. There is withal a lack of that wealth of alcoves and niches which characterise its northern aspect and the eastern edge of the New England rampart generally. To the enormous black palisades succeeds a glacis, abnormally steep, some three thousand feet in height, and protected by long curving buttresses. The wall and slope combined are about four thousand five hundred feet in height. Four distinct basalt layers can be discerned in the parapet face, the upper edge of each succeeding sheet projecting slightly in front of the one immediately above. Dense jungle growths occupy the narrow ledges, and bring into relief the irregularities of the façade. The lava sheets have a horizontal disposition. Each consists of enormous vertical columns crowded closely together.

This gives to the deep curve reaching from Point Look-out to Major's Look-out the appearance of some magnificent theatre viewed from the upper stalls. From the bases of the ravines, more than four thousand feet below, jungle-covered cloaks of talus stretch up towards the apices of the recesses and destroy the individuality of the cliffs at these points. Below and beyond the bays the headlands jut out as great cusps. Reaching out long arms to the valleys, the continuation of these acutely-angled projections present profiles to the heights above like sections of large curves. Up the buttressed spurs the *débris* creeps dwarfing the vertical height of the ramparts. The general impression afforded is that of dismantled architecture, especially of stalls and columns buried in their own ruins. No cliffs or palisades answering to those of the Guy Fawkes arise to the east to suggest a former continuity of the plateau, no mesas or peaks obstruct the view seawards. The eye wanders over an intricate network of gorges cut into the coastal ranges; but so decidedly overtopped are they by the Look-out (five thousand two hundred feet) that the eastern peaks, although often as much as three thousand feet in altitude, appear from our superior position but as ordinary hills. Immediately below the Look-out the drainage from the converging cusps unites to form the headwaters of the Bellinger, which flows thence through mountain and valley tracks to the sea. Each of its tributaries draining the labyrinth of gorges below can be seen in plan. Beyond these the gentler undulations of the coastal area and the white sandy strips of the shore come into view. The great background of all is the sea. Northwards the seaward advance of the forest-clad and basaltic spur separating the Bellinger and Clarence Rivers is a marked feature in the scenery, while still farther north the valley and plain tracks of the Clarence itself may be discerned. A break in the individuality of the mountain belt to the south locates the union of the Macleay head-streams, preparatory to making its magnificent burst through the great Snowy Range in a gorge thousands of feet in depth. Thence in all its windings, as it emerges from the mountain to the valley zone, the river may be traced to Kempsey, where it suffers a sudden deflection to the north. Sand flats and monadnocks occur at this point. Nearly a hundred miles away the distant peaks of the Lower Manning and Clarence Rivers appear as low clouds or mere smudges on the horizon.

Between Major's Look-out and the Snowies a series of cañons preserving an infinity of detail and beauty encroach upon the upland. These, however, mark the recession of waterfalls, and point to an isolation of the plateau-peninsula in the near future. Each niche in the cañon-walls is occupied by a brawling stream which cascades furiously from the first jump over the basaltic columns. With the palisades of the various Look-outs, however, the case is different. The eastern cliffs constitute the highest points along the basaltic plateau. The drainage is, therefore, away from the cliffs. No mighty waterfall or leaping torrent breaks the uniformity of the grand sweeps of their embayments to tell the story of cliff sculpture by debris-loaded streams. One sees here instead a magnificent example of weathering aided by rock structure, the columnar character of the basalt causing the cliff to scale off in great vertical slabs nearly two thousand feet in height.

The chief points to be noticed in the topography, as seen from any of the main Guy Fawkes' Look-outs, then, are—

(*a*) The abrupt termination eastward of the plateau, all the mountains thence to the coast, with the exception of the long basaltic spur, separating the Bellinger and Clarence basins being at least one thousand five hundred to two thousand feet below "The Look-out."

(*b*) The rampart, one thousand five hundred feet in height, which forms the eastern margin of the plateau, the basaltic character of this columned façade (Pl. XXXIII, fig. 1), the base of Palæozoic slates, and the general absence of basalt from the coastal mountains.

(*c*) The great break in the high plateau through which the Macleay effects a passage to the coastal area. Here the eastern margin of the upland is about one thousand feet higher than the general level of the Sandon peneplain, and the river at the gap is only about five hundred feet above sea-level.

(*d*) The marvellous network of gorges into which the coastal mountains have been cut up, and the total absence of a land surface approaching the nature of a table-land.

(*e*) The highest level of the plateau exists at or near its eastern margin. The Snowy Mountains, partly granitic and partly basaltic in origin, stretch along the eastern portion of the uplands. The head-waters of the Macleay rise in this range, and flow thence first in westerly courses and later in meridional directions, until, effecting a junction, they flow eastwards, cutting clean through the range in so doing. At Carrai and Kunderang, in the locality of the water-gap by which the Macleay seeks the coastal area, may be seen some of the finest cañons in the State. Viewed from the streams, the blocks into which the granite and basaltic plateau has been cut resemble lofty and inaccessible mountains; from the summits of the uplands the waterways are seen to be merely a series of trenches or holes traversing an uplifted plain.

South of the Macleay watershed the higher level of New England is well developed. (Map of New England plateaus, Pl. XXXVIII.) The Sandon peneplain is much contracted. The uplands, like those between Armidale and Glen Innes, consist of Palæozoic rocks capped by basalt. The Hunter and Manning divide is for the most part Carboniferous rocks thrown into magnificent folds, and intruded by still later granites. The basalt in many cases cover old auriferous river drift; while, in rare instances, granite forms the highest points of the table-land. In the neighbourhood of Hanging Rock, Callaghan's Swamp, and Nowendoc the plateau is mostly of basalt, while south of this it has been so cut up by the Hunter and Manning streams that huge isolated flat-topped basaltic masses (Pl. XXXV, fig. 1) now alone remain to indicate its former great extension. From the Tomalla and Barrington Tops the country is seen to decrease in height eastwards; very gradually at first, then more suddenly. At Bulladelah the height is nearly a thousand feet still. Above this decreasing slope higher points arise. Among these may be mentioned the Three Brothers of the Manning, the highest of which is nineteen hundred feet.

A connection is established between the New England plateau on the one hand and the Blue Mountains and Orange uplands on the other, by the Great Dividing Range at the Murrurundi Gap. Here the individuality of the table-land is lost, and narrow ridges from two thousand to two thousand five hundred feet above sea-level form a connecting link to numerous partially isolated masses possessing sub-horizontal summits, and about four thousand feet in height. These afterwards crowd more closely together, and become co-extensive with the central and western highlands of the State.

The low gaps mentioned above form the watershed between the Hunter and Peel streams. The former of these rivers is here encroaching on the Peel River catchment area.

The Western Slope.

Westward of the plateau proper the headwaters of the inland system of drainage flow in rough gorges which, from their barren and precipitous sides, might justly be called "bad lands." This first trenching of the upland results in torrent tracks, which are typically lacking, however, in that wealth of great waterfalls which characterise the eastern fall. Beyond this the country is divided into long stretches of fertile flat-bottomed valleys bordered by precipitous mountains. Both valleys and intervening ridges are approximately meridional in disposition. Along the flats the numerous small towns have grown, while the long lines of separating hills are almost worthless for purposes of settlement, being rocky in nature, and clad with growths of cactus, ironbark, and scrub plants.

The main streams, viz., the Castlereagh, Namoi, and Gwydir, flow in a general north-west direction, and cut through the north and south ridges in deep narrow defiles. It is their subsidiary streams which occupy the broad flats with high enclosing dip mountains in the areas of stratification.

Decrease in height is pronounced as one follows the table-land and its residuals in the direction of flow in the large consequent streams. In this connection one must carefully separate out the high peaks and ranges which rise far above the general levels of the Sandon and Mole peneplains. They will be found, almost without exception, to have thick cappings of basalt or trachyte of ages post-dating that of the Mole Plain. Such are the giant and bizarre forms which characterise the Nandewar and Warrumbungle Ranges. The influence of these later lavas on the topography must be thoroughly grasped, otherwise the western aspect of the plateau will be unintelligible.

Adverting to the consideration of the slopes of the Stannifer, Sandon, and Mole peneplains in a western direction we find that at Emmaville the Stannifer Plain is two thousand nine hundred feet high, while above it rise the residuals of the Mole table-land. Decrease in height is still more pronounced west and north-west of Strathbogie. Residuals of the Bolivia, Mole, and Stannifer levels occur all much cut up by the action of the Barwon and its tributaries, and reduced in altitude. At Tingha the three thousand two hundred feet level has fallen to two thousand eight hundred feet. Granite masses, possessing sub-horizontal summits in rare instances, rise from the general flat to a further height of one thousand feet. Basalt-capped tin leads occur on the two thousand eight hundred feet level, as also along the valleys of recent geological age. Flat-topped areas two thousand two hundred feet above sea-level compose the upland west of Inverell, while in the neighbourhoods of Bingara and Warialda the level has fallen to two thousand and one thousand seven hundred feet respectively. A similar loss in general altitude is noted between Woolbrook and Gunnedah.

With increased westing the recent river valleys increase in width and altitude. Moree, Narrabri, Gunnedah, and the country immediately west of Coonabarabran mark the limits of the ranges, beyond which the country stretches in wide unbroken expanses of black-soil plains, gradually decreasing in height from six hundred and fifty feet above sea-level to that same level nearly one thousand miles distant.

A fuller account of the topography of this region will be given when dealing with river characteristics.

The Coastal Area.

The remnants of the high-level plains are not easily recognised as the coast is approached. The absence of flat-topped mountain masses and the other features of advanced land degradation make the conception of a double cycle of elevation almost impossible to the casual observer of coastal forms. Only by a study of the plateaus can the coastal topography be interpreted.

From Point Danger southwards to the Macleay River the coastal district is characterised by mountain ridges and long rolling hills, separating wide fertile valleys, drained by such streams as the Tweed, Richmond, and Clarence. (Pl. XXXVII, fig. 4.)

Isolated mountains, varying in height from fifteen hundred to three thousand five hundred feet, rise from low-level areas not far removed from the shore. Mount Warning lies at the head of the Tweed, is three thousand five hundred feet in height, basalt-capped, and surrounded by hills two thousand feet above sea-level. Clarence Peak and Yarrahappini, in the neighbourhood of the Lower Clarence and Macleay respectively, are associated with extensive sandy plains many miles in length and breadth, and raised but a few feet above the reach of the highest tides. The rivers are bar-bound, and near the points at which, from their main easterly direction, they might be expected to reach the sea, they suffer deflection to the north-east (Pl. XXXVIII), leaving the large sandy plains just mentioned between their present mouths and the points at which one might reasonably have expected them to have entered the sea formerly. Sandstone cliffs at times close in on some of the streams, causing them to flow in narrow channels, while the river itself is within tidal influence. Gently swinging curves are characteristic of this north-eastern coast-line. Examples of lagoons and lagoon-marsh meadows are recorded by various observers.*

Immediately north of this portion of the New South Wales coast similar conditions prevail. In the Brisbane district undulating hills approach the extensive river flats. Further inland high mountains arise, abutting in great escarpment form into extensive sandy flats a few feet only above tidal influence. From the centre of these coastal plains rise isolated peaks of most fantastic forms. These are the famous Glass House Mountains, trachytic in origin. Morton, Stradbroke, and Frazer Islands belong to this coastal area, and have been described elsewhere by the writer.† These are of great height and size, of sandy composition, possessing nuclei of continental rocks, and long swinging coast-lines. The associated mainland coast contains large lagoons and lagoon-marsh meadows.

Southward of the Clarence and Bellinger, as the Macleay is approached, the broad coast curves become less pronounced. Bold headlands advance into the sea. (Pl. XXXVI, fig. 2.) Islands and skerries—rare phenomena along the extreme north—become more frequent towards Port Stephens to the south. Large indentations break up the outline of the coast and show a wealth of lakes, repeatedly ramifying fiord, and densely-wooded mountain spurs reaching far into the quiet waters, as at Lake Innes, Myall Lakes, and Port Stephens. The streams emptying into these lakes have at times meandering courses through wide tea-tree covered alluvial flats a few feet above high-water mark.

The coast advances in subdued mountainous form to within a few miles of the Hunter River mouth, and stretches thence as extensive flats, sandy in nature. The Hunter Valley is seen from this low-lying shore to be very extensive, the mountains retreating far inland.

* J. E. Carne, Ann. Rept. Dept. Mines N. S. Wales for 1895, p. 151; G. A. Stonier, Ann. Rept. Dept. Mines N. S. Wales for 1894, p. 180.

† Notes on Geology of the Queensland coast. Proc. Linn. Soc. N. S. Wales, 1902, xxvii, pt. 2, p. 152.

We should, therefore, in any complete system of adjustment of streams to structure expect to find in areas outside the sphere of granite influence in New England,—

(*a*) A series of streams following the prevailing strike, viz, north and south approximately.

(*b*) Resistant strata and structures composing the highlands, the valleys following the lines of least resistance east and west of the central igneous masses.

In areas flooded by late basalts, deviations from this scheme must be expected.

In the western area the disposition of the towns will be found to be fairly north and south. Consider, for example, the journey from Warialda to Nundle, a distance of one hundred and sixty miles. A glance at the map of New England (Pl. XXXVIII), shows the towns of Warialda, Bingara, Cobbadah, Barraba, Manilla, Tamworth, and Nundle which line the route to be arranged north and south of each other. For the whole distance the track follows a series of flat-bottomed valleys, maintaining a fairly even breadth and bordered east and west by high "dip" mountains whose individuality is only broken here and there by deep side defiles through which the large consequent streams such as the Peel, Macdonald, Namoi, and Gwydir pierce the ranges. The differentiation of the flats into separate valleys is effected by low divides, which, running east and west, join hands with the resistant masses of meridionally-arranged Devonian and Carboniferous strata enclosing the valleys. Withal, however, the height of those low divides or gaps are insignificant when compared with those of the enclosing hills. No towns occur for considerable distances east and west of this line of valleys, the country being occupied by rough mountains, and where settlement obtains again, as at Narrabri and Gunnedah, their communication with the series of towns under consideration can only be effected by means of rough bridle-tracks over the high intervening ranges or by following the tortuous courses of master consequent streams through the hills.

Each of the valleys just mentioned is drained by a subsequent stream. Thus that north of Bingara is occupied by Myall Creek, and that for nineteen miles south of the same town by Hall's Creek. The road is seen to follow the general course of the streams, and the strike of the softer bedded rocks. Nineteen miles out from Bingara a gap known as the "Devil's Elbow" is crossed. The Namoi waters are now entered upon, yet the general direction of road, stream, and mountains is unaltered. Cobbity Creek is then followed. The Manilla, a strong subsequent stream, captures this in turn, and from Barraba to Manilla the river valley is adhered to. The valley broadens, the Macdonald captures the Manilla, the approaching confluence of the two large consequent streams—the Peel and the Macdonald—reduces the size of the mountains, and another subsequent stream being picked up, the Peel is reached, which here is transformed from a consequent to a subsequent stream, flowing

in a broad valley from ten to fifteen miles wide, of its own making, and excavated out of soft strata, the resistant masses of granitic New England forming its eastern border. Thence for forty miles with ever-decreasing breadth the subsequent Peel is followed to Nundle, being bordered by the same red jasperoid rocks which characterised the mountain masses at Bingara and Manilla.

Quirindi, Werris Creek, Breeza, Gunnedah, and Narrabri form another town series comparable with the Bingara-Nundle system.

The Namoi.—The head waters of this stream, viz., the Peel and the Macdonald, rise in the high basaltic country in the neighbourhood of Callaghan's Swamp, Hanging Rock, and Niangala.

The former, draining an extensive area of granite and indurated slate, pursues an irregular course by Woolbrook and Bendemeer, and for many miles beyond. Reaching the stratified rocks near Manilla, it picks up the river of that name, and below this point is known as the Namoi.

With the Peel the case is different. Within a few miles of its source it reaches the highly inclined Devonian beds, and proceeds to establish itself in the weaker layers as a strong subsequent stream. From Nundle to Tamworth its valley rapidly widens. Still maintaining its subsequent course it flows into Attunga, with the high enclosing "dip" mountains of Currabubula on the west, and the hard granite rocks of New England to the east. Beyond Attunga it flows as a consequent stream through the ranges until captured by the Namoi, when the united rivers find a way through the mountains to Gunnedah. Here a subsequent course is again followed to Narrabri, the subsequent Mooki being picked up on the road. At Narrabri the slope of the later coastal plain is followed until the Darling River is reached.

The study of the Namoi is most fascinating, captures of consequent streams by stronger subsequent ones are very common in the history of this stream, and the long parallel ridges of resistant mountain masses that accompany its tributaries appear explicable only on the theory of plateau carving by subaerial denudation.

The Gwydir, or Big River, rising in the high basaltic area of the Guyra Plain, pursues a tortuous course through granite, porphyries, and basalt to Bundarra. Thence to Moree its way lies through roughly parallel ranges of "dip" mountains, rising to the same general height, but preserving occasionally on their summits remnants of higher peaks. Near Bingara the river enters a dense hard belt of red jasperoid strata, and its valley therein is contracted to a defile only, a striking contrast to the broad valley it enters upon at Bingara, and a result of the work of its own subsidiary streams. In the ravine by which the Gwydir leaves the eastern ranges the stream flows in pronounced meanders, illustrating the methods by which it seeks to broaden its valley. Soft strata characterises the rocks in which the

Bingara valley has been excavated, and here deep alluvial flats mark the plain track of the main stream. Flowing now rather along than across the valley, it creeps round the bases of the enclosing mountains to the north-west, and then swinging clean across the track of its subsequent streams it receives the perfectly developed subsequent stream known as the Rocky, or Horton River, whose meridionally-disposed valley is even more pronounced than the Bingara examples. Thence skirting the towering peaks of the Nandewars, it completely breaks up the individuality of the ranges in its advance. At Moree the mountains have been left far behind, and beyond this point the sluggish river meanders through deep, fertile, "black-soil" plains, which, even when viewed from the eastern ranges, stretch far away beyond the limit of vision.

The Dumaresq, Severn, Mole, and Macintyre Rivers, which form the head-waters of the Barwon, drain the western portion of the Bolivia, Mole, and Stannifer peneplains. The three levels of these plains all represented in this region by many residuals, and the gulches post-dating the latest upheaval of the plateaux, give tumultuous profiles to the present ravines. Waterfalls as much as one hundred and seventy-five feet deep occur in places along the watercourses. The country drained consists mainly of hard granite of various ages, felspar and quartz porphyries, and indurated claystones. The higher and older plains, as also the present valleys, are seen to have been developed, at the expense of the least resistant structures, beautiful examples of stream adjustment to structure being frequently encountered between Tenterfield and the Dumaresq.

Eastern Rivers.

Of these, all the principal members take their origin in the plateau flowing slowly on the uplands for varying distances through very broad valleys. An eastward course is not necessarily followed at the outset, for, as will be shown in the description of individual streams, the head waters of certain important rivers maintain westerly directions for many miles, before turning finally to the east. All possess very pronounced mountain tracts, though the torrent paths present marked variations in appearance. Each stream has its characteristic valley and plain course as also its torrent track. The scenery of the streams along the coastal area is also characteristic. Subsequent drainage is a marked feature here as in the west, though not possibly so pronounced, owing to the encroachment of the granite on the eastern fall and the consequent induration of the surrounding slates. Although the dominant strike is north and south, great variations from this common direction have been set up by earth movements. Thus in the Walcha district the trend of the rocks is almost east and west, which many miles away is still north-west and south-east. Naturally, then, numerous subsequent streams will be found not possessing even an approximately meridional direction of flow.

The rivers for convenience may be grouped as follows:—

(*a*) Tweed, Richmond, Clarence, Bellinger, Macleay, and Hastings.

The Tweed, Richmond, and Clarence Rivers take their origin in the peaks of the Macpherson Range, the basin of the latter almost completely encircling those of the other two.

Of these, the Tweed has a short path only to the sea. Importance attaches to it mainly from the marvellous scenery of its valley and the fertility of the hill slopes of its lower course. Taking its rise in Mount Warning, an isolated peak of the Macpherson Range (Pl. XXXVII, fig. 2), its valley illustrates the maturity to advanced maturity of mountain dissection in that locality. A few miles from its source it comes within tidal influence and flows between steep wooded hills, covered with dense cedar, pine, beech, and box forests, jungles, and plantations of banana and sugar cane.

Alternating hard and soft strata of Permo-Carboniferous or Carboniferous age much folded and small bosses of later granite form the basal rocks of the district. Above them lie horizontally bedded sandstones, soft tuffs and shales, and basalts of the Trias-Jura, while on these in turn lie the markedly columnar basalts belonging to Tertiary time.

The above arrangement formed a weak geological structure. It is the mixture of "the iron and miry clay," the magnificent and strongly-knit superstructure erected on a crumbling foundation. The whole mass is calculated to succumb readily to the onslaught of the forces of subaerial denudation. The basalt itself resists strongly the efforts of erosive agents, so also the horizontal disposition of the sandstones and the dense hard nature of certain varieties of the sandstone make for endurance of topographical forms. The underlying weak folded shales and softer slates of late Palæozoic age, as also the great amount of soft tuffs and shales intercalated with the harder sandstones of Jurassic times, when once exposed by vertical corrasion readily fret away, and cause the overlying rocks, however hard, to fracture and fall into the valleys in wholesale manner. The markedly vertical columnar structure of the later basalts brings about the rapid demolition of this resistant rock when once the lower strata are exposed.

The Richmond takes its rise in Mount Lindsay, one of the highest points of the Macpherson Range. Majestic isolated forms encircle the head waters of this stream. Their separation is pronounced, large U-shaped valleys being of frequent occurrence. Granite, folded Palæozoic strata, and Triassic rocks of varying hardness form the bases of the peaks, while the perpendicular scarps forming the inaccessible summits of certain of the surrounding mountains consist mostly of columnar basalt, sometimes as much as a thousand feet in thickness. The lower portions of the stream are hemmed in between steep wooded hills wonderfully fertile in character, broken here and there by rich flood plains. Tidal influence is felt eighty miles up the

stream. A little below Lismore the river turns towards the north and empties itself into the sea at Ballina, distant by water from Lismore sixty-five miles and by land twenty miles only.

Waterfalls accompany the river along its upper reaches.

The Richmond and Tweed both lack that definite easterly trend from source to sea so characteristic a feature of the major streams. The local development of the thick basalt mass of the Macpherson Range would naturally impose upon these later and smaller consequent rivers their south-easterly directions.

Of greater importance is the Clarence, two hundred and seventy miles in length, and possessing enormous "bottom flats" unsurpassed for fertility. The head waters of the main or north arm are meridionally disposed, the principal of which rises in the mesa, Mount Lindsay. Various tributaries such as the Koreelah and Tooloom join it from the north and the Boonoo Boonoo, Cataract, and Rocky Rivers from the south.

The Koreelah flows in a broad U-shaped valley when traversing the Jurassic strata, which becomes contracted into a gorge in the indurated slates of the Rivertree area. So also with the Tooloom. The Boonoo Boonoo and Cataract Rivers flow for considerable distances along the granite table-land, here two thousand nine hundred feet in height, thence cascading over high granite ledges, they dash along through narrow mountain tracks to join the parent stream.

The adjustment of streams to structure is admirably illustrated in the case of the Clarence. As in the instances of the Richmond and Tweed the association of thin alternating beds of hard and soft strata, of columnar basalt and weak basal geological structures, cause even the head waters of streams on leaving the table-land to occupy broad valleys. The occurrence of thick beds of hard horizontally-disposed sandstones, however, promotes the confinement of the streams to narrow channels. This is well exemplified in the case of the Clarence at Koreelah and Copmanhurst. The water gap (Pl. XXXVI, fig. 3) of the Tweed at Byangum Crossing is another example. Granite and indurated slate country keep the contained streams cribbed and confined for many miles, while in contiguous areas composed of weaker Triassic strata, the streams belonging to the same system have reduced the high ranges to a series of undulating hills.

Mount Lindsay affords a magnificent example of the differential erosion of overlying columnar basalt and underlying Palæozoic rocks. The columnar structure has been instrumental in maintaining vertical faces in the basalt cap, the resistance of the basic rock itself to the same agencies allowing the cap to preserve its flat appearance, while the mass disappears by recession of the walls, the rapidity of such action depending on the resistance offered by the basal structures. Wilson's Peak, Mount Leslie, Clunies, and Mount Barney afford similar illustrations of the selective

action of denuding agencies. Along the valley of the Tooloom two immense dome-shaped masses stand out in marked isolation from the smaller neighbouring hills. They are known as the Beehives or North and South Obelisks. Masses of hard volcanic rocks forced through the softer surrounding strata, they exist as monuments of endurance, while the once enclosing masses have long since been removed.

The Boonoo Boonoo heading in the residuals of the Bolivia peneplain flows sluggishly for many miles over the two thousand nine hundred feet level. The country is granite. The falls by which the river leaves the table-land are seven hundred feet in height, and in approaching them the stream incises its way into the upland in an ever-deepening channel, until at the point of precipitation over the series of ledges forming the falls it occupies a gutter some two hundred feet below the general level of the Stannifer Plain. A deep pool exists at its base, in which large rounded boulders occur. Below this point the stream winds for twenty-five miles through a steep-sided trench, one thousand eight hundred to two thousand feet deep, joining the main river at Rivertree. The flat surface of the granite plateau occupies both sides of the cañon.

The Cataract River has a similar history to that of the Boonoo Boonoo. The Boorook Creek, a tributary of the Cataract, has a fall one hundred feet only in height, but interesting by reason of its method of occurrence. The Permo-Carboniferous rocks here consist of gently-inclined rhyolitic tuffs and lavas near the junction with later granites. The stream in sinking its way through the tuffs discovered a large and excessively hard rhyolite sheet, whose recession has formed the falls, being more slowly disintegrated than associated rocks.

Widely different, however, are the characters shown by the falls and mountain tracks of the southern Clarence. Here the plateau is much higher than in the north, and varies in composition and height from a granite upland four thousand-four thousand five hundred feet high to a basaltic one rising from four thousand five hundred to five thousand feet above sea-level, the highest points occupying the most easterly edge of the plateau proper. The principal streams head in the Guy Fawkes, elsewhere described in this report. Numerous waterfalls occupy the heads of the niches, and larger recesses which break up the northern and north-eastern aspects of the plateau. In the faces of the cañon walls may be seen magnificent sections of the Tertiary basalts.

Among the many falls the principal are the Marengo and the Ebor. A separation into an upper and lower fall is generally effected by means of varying degrees of composition and structure in the basalt. An inspection of the Ebor Falls reveals two drops, separated by a horizontal shelf about one hundred and fifty yards in length.

A mass of coarse porphyritic basalt has cooled out in immense vertical columns, individual prisms attaining a diameter of seven feet. The columnar structure is well shown in the face. (Pl. XXXIII, fig. 1.) The section of a small and exceedingly vesicular basalt is exposed in the face. Another fall, some twenty feet in height, is determined by the sandwiching in of a layer of fine grained lava, showing a wealth of slender prisms. A thin layer of incoherent tuffs forms a base to this Pumiceous fragments characterise this soft ash-bed, and its presence between the hard lavas has given rise both to the flat and the amphitheatre, into which the upper waters cascade.

The floor is formed of dense columnar basalt, the prisms being inclined generally at angles of 45° to 60° to the horizon. This sheet of inclined columns attains a thickness of about one hundred feet, being succeeded immediately below by huge vertical prisms. Here, again, the basalt is coarser and porphyritic, with large clear labradorites, as in the uppermost layer. The lower Ebor Waterfall is from two hundred and fifty to three hundred feet deep. A similar series of tuffs, vesicular and dense basalts, may be seen in the sections made by the other falls in the plateau. Some exhibit a thin layer of small columns, surmounting the large prisms, as at Station Creek Falls. (Pl. XXXIII, fig. 1.) Ropy and slaggy structure is distinctly observable along the exposed surfaces of certain layers, in all cases associated with great quantities of flattened vesicles, often as much as twelve inches in diameter.

The country above the falls is rudely terraced, the appearance being determined by the action of erosion on basalt and tuff layers of varying texture and basicity.

The basal beds consist of granites, claystones, and slates. The section (Pl. XXXIX) illustrates the relation of the Snowy Mountains, the Guy Fawkes plateau, and the eastern Palæozoic rocks.

Other tributaries of the southern Clarence head in high granite country, and form falls characteristic of granite scenery.

The mountain tracks of all these streams are very long and of pronounced type. One may travel along the streams for many miles through deep, gloomy V-shaped gorges from two thousand five hundred to three thousand feet in depth. Their direction is frequently meridional, the junction of slate and granite often forming a line of weakness readily attacked by the granite. This junction is almost without exception auriferous. Other streams follow subsequent courses determined by the strike of the slates or the folding of the strata. Possibly some of the wildest gorges along the Clarence are those not far above the confluence of the south and north arms. Here the river is forced to flow through indurated and contorted slate. Side creeks entering it from the north occupy deep gulches in the granite and slate fully three thousand feet in depth, and utterly inaccessible to stock. The higher country is flat-topped, but cattle cannot ascend the spurs leading into this plateau

expanse. The Cooraldooral, Dundahra, and Coombadja are notable examples of such profound clefts in the table-land. Rapids occur in the bed of the main stream, and magnificent examples of potholes are to be seen in the contorted slates forming the bed-rocks. At the Camel's Back, near Gordon Brook Station, the main Clarence is again hemmed in by precipitous hills, and forced to occupy but a narrow gorge. As once more the sandstone and shale country are entered upon the great gorges disappear as if by magic, the valley broadens, and rich flood plains are laid down between the rolling hills. Slight rapids occur along the lower course of the river, and are doubtless referable to the later slight folding associated with the recent coastal elevation. The Orara, a strong subsequent stream flowing almost parallel to the coast through beds of Jurassic sandstone, joins the main stream a few miles below Copmanhurst. Tidal influence is felt as far up the river as this point, a distance of eighty-five miles from the sea. Between Copmanhurst and Grafton the river is often confined between two high walls of perpendicular sandstone.

The Bellinger is an insignificant stream, and in common with the equally short consequent Nambucca heads under the Guy Fawkes Look-out. It receives no drainage from the plateau, as the highest points of the same are ranged along its eastern margin, which, with the high granite, swerves immediately to the west from the main divide of the State at this point. From Point Look-out the country slopes precipitously for four thousand five hundred feet to the spot where the Bellinger takes its origin. From the plateau a long basaltic spur extends easterly, decreasing in height as the sea is approached. This forms the watershed between the south Clarence and the consequent Bellinger. The dense forest and semi-tropical jungle occupying its slopes is known as the "Dorrigo Brush."

From the Guy Fawkes the watershed follows approximately the eastern margin of the plateau for many miles. Flat-topped and basalt-capped, it rises about one thousand feet above the general level (three thousand three hundred feet) of the far-reaching Sandon peneplain to the west. The Macleay itself is formed by the union of the subsequent streams known as the Apsley and the Chandler. Rising to the west of the main divide, they receive innumerable obsequents from the western escarpment of the Snowies, and flow in deep set gorges before assuming a consequent direction, and bursting through the opposing flat-topped range to the east. Characteristic of this watercourse are the stupendous waterfalls of its narrow and deep head-water cañons; the persistence of the general flat of the Sandon and Guyra peneplains beyond the points at which the gorges commence to cut up the plateau, the gap by which the stream leaves the main range, and the grandeur of the ravines at the place where the individuality of the upland is passing away, isolated masses taking the place of once co-extensive plains. The Apsley, Tia, Yarrowitch, Wooloomumbi, and other head-water streams originate in the marshes of the high basaltic table-land. Thence to the three thousand three hundred feet level they possess rapid

courses, but once established on the Sandon plain they flow slowly until they precipitate themselves into the inaccessible gulfs leading to the coast. These gulfs, marking the recession of the streams, are mostly excavated in highly-inclined slate of varying hardness. (Pl. XXXVII, fig. 1.) The Apsley Falls have retreated at least fifty yards during the past thirty years. The upper fall is two hundred and fifty feet in height, the lower one three hundred feet. Thence the torrent track quickly cuts its way two thousand feet below the general level. About a mile and a half below the falls the gulch is ten chains only in width and eleven hundred in depth. A tributary gorge in one place is but seven chains in width and one thousand feet deep.

The Tia leaves the plateau in two falls aggregating one thousand feet in height. A mile and a half below the "break" the cañon is half a mile in width and two thousand feet in depth. This gulf is excavated in inclined slate of Palæozoic age, as is the case of the neighbouring Apsley. The Tia, however, furnishes a more imposing spectacle than the Apsley. Its valley is broader, and is recessed with innumerable alcoves and niches where subsidiary streams have eaten their way into the plateau while cascading into the main channel. Long knife-edged spurs extend like buttresses from the sides of the ravines to the base of the principal valley.

The Hillgrove gorges * illustrate the action of streams on cuboidally-jointed granites or on slates at the junction of intrusive granite, the plutonic rock having exercised a hardening effect on the slates—a feature absent in the cases of the Tia and Apsley slates. The falls are generally five hundred feet in height, and take sheer flights over the ledges of granite, which appear as gigantic piles of masonry. The Apsley River is reached by these streams after flowing for some miles along graded tracks.

The Mihi and Dangar streams fall over great ledges, many hundreds of feet in height. The existence of these gulfs would scarcely be suspected at a distance of five chains.

Grandest of all the gulfs or amphitheatres into which the streams throw themselves is that of the Wooloomumbi. At the head of this gorge the Wooloomumbi and Chandler effect a junction. The depression at its head is almost semi-circular in plan, its width is probably about two hundred yards, and its depth is sixteen hundred feet, with almost perpendicular sides. Both streams have eaten shallow basins in the general level of the Sandon plateau preparatory to occupying their lower valleys. There is no warning that the country is about to break away, the Wooloomumbi simply leaves its narrow channel, now some six hundred feet deep, and takes a leap of one thousand feet into the abyss. Alongside, the Chandler joins it in a series of gigantic bounds totalling some fifteen hundred feet. Thence the

* E. C. Andrews.—Report on Hillgrove Gold-field. Dept. Mines N. S. Wales, Mineral Resources, No. 8.

united waters flow as a strong subsequent stream; the deeply trenching Apsley is gathered in, and the consequent Macleay formed, which straightway proceeds to force itself through the high opposing basaltic range to the east.

All of these falls, the Tia, Apsley, Wooloomumbi, and Chandler, furnish important examples of corrasion in highly inclined slate beds.

Grandeur of appearance, as far as cañon structure is concerned, finds its maximum expression in the neighbourhood of the gap by which the Macleay leaves the Snowy Range. From the river-bed, three thousand five hundred feet below the plateau, the precipices of Carrai and Kunderang appear as lofty mountain piles. From the Guyra Plain one sees successive peaks rising on each other's shoulders in the gap until their higher summits merge into the far-reaching basalt plain, while side torrents force their way through narrow gorges with almost perpendicular sides more than half a mile deep into the main channel. So contracted are certain of the gulches, as Kunderang, that they appear as clefts dealt by some Titan axe in the plateau.

An examination of the Macleay gorges reveals a marked absence of that variety of detail which characterises cañon forms developed in horizontal strata varying in thickness and resistance to erosion. Parapets and terraces are absent save in the case of basalt-capped areas. Vertically considered the structures are similar. Differences exist horizontally. Instances of this horizontal disposition of variable topographic forms occur where granite masses in slate areas are exposed, and reach up from the valleys after the similitude of giant masonry, or where more resistant belts of slate or claystone stretch across and along the valleys, thereby causing local constrictions, the strata themselves weathering out in rugged needle-shaped masses hundreds of feet in height.

All of the Macleay falls possess deep pools at their bases, in which great rounded stones occur. These, in flood-time, are dashed against one another to carry on the work of excavation.

A feature forcing itself upon the attention of even the most casual observer of the Macleay basin is the marvellous persistence of the general level of the plateau even after the establishment of deep cañons upon its surface. (Pl. XXXII, fig. 1.)

Eastwards of Uralla, Armidale, and Walcha, as far out as the basaltic plateau of the Snowies, the slate and granite mass of the Sandon Plain is literally cut up into a network of impassable ravines. Yet strangers to the district viewing this cañoned area mistake it for a solid plain. Beyond the Snowy Range, however, no sign of former plateau exists, except to the eye of the experienced observer. But for the later basalts which flooded the floor of the imperfectly-developed Sandon Plain the plateau would, by this time, have entirely lost its individuality as far west at least as the Great Northern Railway line.

Another interesting feature especially well illustrated in the case of the Macleay waters is the extremely rapid approximation of streams to base-level and the development of graded courses. Baker's Creek, which is simply an ordinary ravine of the Sandon peneplain, is chosen for description in this connection because well-known,* although its study affords but a slight idea of the grandeur of other Macleay gorges. The gully starts with a fall about five hundred feet deep over granite, thence flowing as a torrent track (Pl. XXXIV, fig. 1) for about three miles with a course much obstructed by huge boulders, it develops numerous sandy flats along its banks. From this point, at which it has incised itself some sixteen hundred feet into the plateau, its bed may be followed on horseback to its junction with the Salisbury waters, which, also uniting with the Apsley, flows with graded course between high spurs, until the Macleay Gap is reached. Here the river is about five hundred feet above sea-level. The river is, however, not yet clear of the mountain zone, although aggradation flats become more pronounced in size. About seventy or eighty miles above the mouth of the river, the valley track is entered upon, the mountains recede farther and farther from the river, and stand up as conspicuous well-isolated peaks, large fertile flats occupying the area in the vicinity of the stream.

An examination of the Hastings River basin emphasises the idea that old-age river basins belonging to a former cycle of erosion have had their streams revived in part at least by an uplift in late geological time. This smaller consequent stream is completely encircled by the Macleay and Manning basins, and is separated from the head waters of these streams by a flat-topped basalt-capped range four thousand feet in height. The mountains separating the tributaries of the Hastings, as the Forbes, the Wilson, and the Ellenborough, show a gradual decrease in height from four thousand three hundred feet at the "black scrub" covered "tops" at the head waters to a few hundred feet only at the neighbouring coast-line. Many of the ridges are flat-topped. Mature valleys have been developed at the expense of the once continuous plateau. The arrangement of the streams reveals a beautiful relationship between surviving ridges and hard structures, as also between valleys and softer rock characteristics. Isolated peaks rise high above the general slope of the elevated peneplain.

Probably in former times this consequent stream possessed much greater importance than at present. The flooding of the partially-formed Sandon Plain by basaltic lavas, however, modified the courses of the Macleay, Manning, and Hastings, these streams having approximately determined their present directions of flow before the late Tertiary uplift, the elevation simply reviving their former activities. With the energy of swiftly-falling streams, the Hastings is gnawing backwards into the basalt range—here, however, of extreme hardness—and threatening to capture

* E. C. Andrews.—Report on Hillgrove Gold-field, pp. 12, 21, and 22.

the Yarrowitch from the Macleay system. The Yarrowitch meanwhile is rapidly entrenching itself in the softer slates to the west, and will, doubtless, before the breaking of the divide by the Hastings, have so well developed its cañon in the Sandon Plain to a depth near to base-level, that the competence of the steeper Hastings to accomplish its capture will be reduced to zero point.

Manning River studies furnish excellent illustrations of the varying resistance of inclined Palæozoic rocks to the forces of erosion. The accommodation of the streams to surrounding structures is particularly marked along the courses of the southern branches of the river.

The map (Pl. XXXVIII) shows the general distribution of its tributaries, as also its relation to the Hunter River.

The plateau is here much degraded, the divide between Manning and Hunter streams consisting of numerous flat-topped basalt-capped mountains, once continuous over a very large area, but now far advanced into the mesa-stage. Two levels exist here, as in New England proper, the prevailing one being about four thousand five hundred feet above sea-level, broken by higher basalt and granite patches attaining a height of five thousand feet. This four thousand five hundred feet level is a southern extension of the Guyra Plain. Omadale, Gummi, Tomalla, Timor, Black, Barrington, Ronald, and Woolloma Tops are relics of the once coextensive plateau, the Barrington Tops, however, consisting principally of granite. So well dissected is the Guyra Plain in this district, that the Manning and Hunter at one spot are separated by a narrow gap only, fully fifteen hundred feet below the general level of the surrounding "tops." Although the Manning basin is of considerable extent, it will be seen from the general map that the Hunter overlaps it to the west.

From Cary's Peak, five thousand feet in height, the net-work of wild ravines occupying the greater portion of the Manning River basin can be well studied. Profound defiles, separated by long ridges, are of frequent occurrence, with higher masses rising above the general level. Great mountain blocks, of irregular shape, are to be found in various portions of the basin, one side presenting enormous cliffs to the valleys below, the opposite slopes being comparatively gentle. These masses also far exceed the general height of the associated ridges, and mark the existence of enduring dip mountains, relics of the Mole peneplain during the previous cycle of erosion. Examples of such relict masses are furnished by the Comboyne Hills, the Brothers, and other peaks; while instances surviving from the Sandon peneplain, or its eastern extension, are furnished by the Gloucester and Dewitt Buckets. The ridges separating the streams are characteristically of razorback habit, and ramble in and out for miles.

Generally, a steady decrease in height for the remnants of the Sandon peneplain is to be noted as the sea is approached.

Three main channels can be made out in the basin—those of the Barnard, Barrington, and Little Manning. After passing through the mountain tract, where the gorges are V-shaped and from two to three thousand feet in depth, the principal streams flow through broad valleys. The enclosing mountains are, however, quite as rugged as those of the torrent tract once the broad, maturely-developed valleys are left. Below Wingham and Taree extensive flood-plains are developed. These are of extremely fertile nature, owing to the vast quantities of volcanic tuffs and basalts drained by the streams. A traverse of the hills enclosing the ravines is often almost impossible owing to the dense nature of the jungle.

A few miles northwards of the mouth of the river, three large isolated mountains occur, varying in height from fifteen hundred to nineteen hundred feet. These are known as the Three Brothers, and one, at least, is a famous example of a dip mountain. The survival of all three is due to the preservative action of a thick and excessively hard stratum of rock. Southwards, well-wooded mountain spurs advance into the sea, having a height of several hundred feet.

The rocks of the basin consist, for the most part, of folded Carboniferous(?) strata. The beds are not usually of great individual thickness, exceptions being the wild escarpments north of Coopernook and Taree, the Dewitt and Gloucester Buckets, the Pigna Barney examples, and others less known along the Little Manning.

The head-waters sink rapidly, almost precluding the idea of settlement along the mountain tracks. Precipices, determined by the more resistant rock layers, sweep up and down the sides of the steep cañons, according to the prevailing dip. Here, as in the corresponding tracts of the Macleay, Clarence, and Richmond basins, communication is difficult, "bridle tracks" or "trails" being the common roads. This part of the basin will, doubtless, even should the State in future support a large population, be kept as a forest reserve, its timber wealth being very considerable. Settlement will be restricted to the small aggradation flats which occur some miles below the falls country.

A very slight acquaintance will be found sufficient to mark the divergence of gully characteristics in the cases of the Manning and Macleay streams. The latter, by reason of their homogeneous structure over great vertical distances, permit of immense cliffs, while along the Manning waters the precipices are generally inconsiderable. Large waterfalls are thus uncommon phenomena along the Manning basin, cascades taking their places. Along the gully bases, however, the paths present more obstacles to progress than those of the Macleay streams. This is also attributable to the great variations in rock structure, whereby hard "bars" or strata are left across the track of the waterway, the less durable ones being easily removed. Thus bedded rhyolites and quartz-porphyries occur, which, being superior in hardness to the associated fossiliferous tuffs, stand out prominently as survivals of the fittest in the process of rock demolition. In this connection, the influence of dip

must not be neglected. The moderate inclination of the rocks of the Manning basin allows of the formation of cliffs and narrow valleys, whereas in horizontally-bedded strata, the discovery by a corrading stream of soft rocks underlying a hard belt would be attended by wholesale demolition of the plateau.

A splendid example of this differential resistance to erosion is the Gloucester Buckets, a series of parallel belts of quartz-felsites (Pl. XXXII, fig. 2), forming a razorback divide between the Gloucester and Barrington Rivers. The divide is less than a chain in width at the summit, its height is about a thousand feet, and it presents an almost sheer cliff to the Gloucester River flat. The separated streams occupy broad flat-bottomed valleys, excavated in softer tuffs.

The Dewitt Buckets, forming a huge cliff-like escarpment about fifteen hundred feet in height on to the Little Manning, at Cognac, furnish an even finer example of surviving rock strata, the Manning here adopting a subsequent course.

Some of the best examples of differential erosion occur along the Dilgry, a tributary of the Little Manning.

The country lying between the Hunter and Manning River mouths is drained by small streams, partly consequent and partly subsequent. Chief of these are the Karuah, Myall, and Booloombayte. (Pl. XL.)

Although insignificant as waterways, except along their lower courses, they furnish admirable examples of the adjustment of streams to structure and the influence of later drowning. The country is composed chiefly of later Carboniferous rocks which have been thrown into a series of folds; Permo-Carboniferous strata, also folded, occur in the valley of the Myall. The old age of the cycle of erosion antedating the late Tertiary uplift had bevelled hard and soft strata off alike, and left a peneplain broken by monadnocks, truly, but much reduced in size. On the uplift, the selective action of the Karuah and Myall streams quickly led to a roughening of the plain now uplifted, the hard belts of the moderately-inclined rocks being thrown into grand relief.

The Karuah is interesting on account of its beautifully-developed subsequent valley. A series of alternating banded spherulitic rhyolites and dolerites of Carboniferous age constitute the bulk of the country rocks. Subsequent streams have been developed, the valleys following the strike of the softer dolerite beds, while the harder rhyolites form steep ridges having a parallel disposition to the trend of the watercourses. Leaving the southern Manning streams by a valley carved out of softer tuffs, and enclosed by hard felsite ridges, a low divide is crossed and the Karuah track entered upon, the latter river being enclosed for many miles by the felsite ridges. Doubtless, excellent illustrations of stream capture may be studied here.

The Myall River is doubly interesting, in the first place, by reason of its striking meandering course through a wide tea-tree covered flat, elevated but a few feet above the sea and bordered by rough steep mountains about one thousand feet above sea-level, the mountains conforming to the general trend of the strike. In the second place, its lower course is an admirable illustration of river drowning, lakes springing from a main waterway like budding leaves from a twig.

From the Bullahdelah Buckets, a razorback ridge, one thousand feet high, composed of spherulitic rhyolites of Permo-Carboniferous age,* the large flat of the Myall can be made out for miles to the north. To the south it can be seen to leave its subsequent course, and sweep across the line of trend of the "Buckets" until the Myall Lakes are reached.

The main course of the lakes is approximately that of the coastal contour, the sea being separated at times from the lake and river system by long, narrow, well-wooded ridges and mountainous spurs.

Port Stephens is connected with the lakes by the Myall stream. The accompanying map illustrates the appearance of this, as also the drowned valleys of the Karuah and Hunter streams. (Pl. XL.)

In a word, the study of the Myall points to a mature dissection of the coastal margin of the plateau, at a period when the coast was extended farther to the east than at present. A mild roughening of the plateau was the result of the initial attacks of subaerial denudation. Afterwards came the discovery of strata presenting various degrees of obduracy to the attack of the swiftly-falling streams, and the diverting of small consequent streams by a stronger subsequent river. The valley of the Myall was excavated in soft strata, while enclosing it on both sides were the more persistent rocks of the region, conspicuous among which are the Bullahdelah Buckets† or Alum Mountain. A moderate subsidence supervened in recent geological time, and as a result of the sinking, the subaerially carved valleys of the lower Myall were converted into a lake system, the alluvial flat of the valley being formed by marine sedimentation. Finally, a slight elevation occurred which carried the flat so formed above the reach of the highest tides.

An examination of Pl. XL shows the wonderful change effected in the coastal topography since the subsidence in recent times. Here "shoals" are seen to have been developed along the coast. The creeks following the contour of the coast are in great part those occupying depressions on the landward side of the shoals. Recent elevation converted the shoals into coastal plains and the depressions into receptacles for creeks curving sympathetically with the coast.

* E. F. Pittman.—Mineral Resources N. S. Wales, pp. 415-417.

† Bucket—a precipitous escarpment.

Magnificent illustrations of the advanced stage of erosion of a plateau gradually decreasing in height on all sides but the north are afforded by a study of the Hunter River. From a study of the Manning, one is hardly prepared to find such an amount of work done as has been achieved by the Hunter streams. Some of the valleys are as much as fifteen miles across, with high, flat-topped mountains bordering the hollows. Even at their head waters the streams occupy broad basins. The rocks of the upper portions of the basin consist principally of Carboniferous volcanic rocks and tuffs, slates, claystones, limestones, and allied rocks. These have been folded into anticlines and synclines of considerable size, smaller foldings being superimposed upon the shoulders of the broader flexures, and all are capped by basalts of various ages. From these masses have been carved the huge isolated mesas, the material lost to the plateau by such sculpturing forming the fertile flood-plains of the lower river.

On the eastern or coastal fall, the Williams drains a belt of country containing numerous alternating rhyolite and dolerite lavas.

Permo-Carboniferous strata of gentle dip occupy the lower and middle portions of the basin, the dip being accentuated in a northerly direction.

Generally, the Palæozoic rocks form the mountain masses to heights of from two thousand five hundred to three thousand five hundred feet above sea-level, above which one commonly meets with an extensive basalt cap. The flat-topped basalt hills are marked features of the whole of the upper and north-western portions of the basin. West of the Great Northern railway line, among the rough country beyond Singleton, Muswellbrook, and Scone, two "terraces" can be made out, the traces of the higher one existing as truncated pyramidal mountains rising from a general level of about three thousand feet.

The coastal tributaries, known as the Williams and the Paterson, present features analagous to those of the Manning streams. Rough, knife-edged ridges and deep gorges abound. Subsequent streams are of common occurrence, and magnificent illustrations of stream adjustment to structure may be perceived along the banks of the Williams River itself. (Pl. XL.)

As the valley of the Hunter is followed down, the mountains may be observed to dwindle in height, the valley broadens, the Goulburn, Paterson, and Williams are gathered in by the main stream, and rich flood-plains spread out for great distances on either bank. Beautifully-formed terraces exist at various points along the river course. Instances have come under the writer's notice at Raymond Terrace and Singleton. Those at Singleton appear to be some fifty feet above the present flood-plain; while the occurrences at Raymond Terrace are extensive, of sandy nature, and about twenty feet above the general "bottom flats." Here, also, the "bottoms" are several miles in width. Coastal plains are pronounced features in the neighbourhood of the river mouth, and the Raymond Terrace "terraces" would come

under this appellation. At the mouth itself a fine example of a "tombolo," or tied island, may be seen, and known as Nobbys. Immediately south of this island and mainland connection, high cliffs of Permo-Carboniferous strata border the sea, at the bases of which outcrops of coal seams may be seen.

Other points of interest attaching to this stream are its threatened capture of a tributary of the Peel River, in the neighbourhood of Murrurundi, and the capture of part of its own waters in turn by the Manning at "The Gap."

A comparison of the Hunter and Manning activities during the present cycle affords an instructive and interesting lesson in the sculpturing of land surfaces from rock masses, presenting many differences in hardness, folding, and relative thickness.

The individuality of the plateau is almost entirely lost in this the extreme south of New England, and the explanation of such loss as the uplands have sustained is not difficult to find.

The late Palæozoic rock masses were folded, causing hard and soft strata alike to outcrop at the surface. No great display of granitic intrusions occur here to produce extensive masses of rock presenting great obduracy of resistance to the forces of erosion as has been the case in New England itself.

The greater portion of the Hunter basin is occupied by soft and hard Permo-Carboniferous strata approximately horizontally bedded.

Along the basins of the Manning and coastal tributaries of the Hunter, the bevelled edges of the vertical strata outcropped on the Sandon peneplain, and the revivification of the streams led here to a magnificent development of subsequent streams; the softer strata were quickly removed, and the more resistant structures left. The very tough and dense rhyolites and allied rocks allow of encroachment by lateral migration of the streams very slowly, and thus old watercourses may be compelled to flow in comparatively narrow channels.

In the case of the Hunter, wholesale demolition of the old upland has gone on, notwithstanding its great capping of basalt. The soft gently inclined beds of the Permo-Carboniferous Series are responsible for this. In the neighbourhood of the coast the Palæozoic rocks had no capping of hard basalt, and the rapid removal of the strata followed on the discoveries of soft shales by the swiftly-falling streams. Many hard belts of rock occur in the Permo-Carboniferous Series, but their strength accounts for very little when once the incising streams have exposed the soft shales and clays below.

Conspicuously hard belts in the Hunter basin are the conglomerates of Salisbury Crags around Murrurundi (Triassic),* and the Tertiary basalts.

* *Vide* T. W. E. David.

It might have been expected that the Manning basin having, at the time of the late Tertiary uplift, a fairly even slope with the edges of the upward strata outcropping along its surface, and not possessed of such an extensive capping of basalt as the Hunter drainage area, besides being an area of greater precipitation, would have exhibited wider valleys and more subdued hills than the region drained by the neighbouring stream.

To the east of the divide in the coastal region drained by the consequent Manning and subsequent Myall, Karuah, Williams, and Paterson streams, the Sandon peneplain had indeed the courses of the revived streams already determined, the dense rhyolites and allied rocks forming in late Tertiary times the enclosing highlands, though more subdued than the present relict mountains. Lengthwise valleys were rapidly formed, but their increase in width proceeded along very slow lines when once the softer dolerites and tuffs had been removed, the acid igneous rocks, conglomerates, and silicious strata resisting the encroachments of lateral corrasion. Crosswise valleys were developed, but were mostly mere ravines as compared with the broad and meridionally disposed lengthwise troughs. Thus the lengthwise valleys of the Gloucester, Karuah, Myall, Paterson, and Williams have existed as such for a long time, the bordering hard mountain ranges only yielding at excessively slow rates, as is evidenced by the crosswise valleys. Dense jungle growths also help to preserve the relict mountains of the Manning and other coastal streams. Frequently these forests and "brushes" are so thick as to require a "brush knife" to effect a passage through them, and freshes may occur in the streams without any perceptible discoloration of the water. In the case of the Hunter, the horizontal disposition of the hard beds, although exercising a preservative influence on the incoherent masses below, could not prevent widespread destruction of the plateau when once these soft rocks were exposed, since sloping gently they permitted the whole mass of the strata to be easily removed to their own level. The absence of dense jungles or "brushes" also allows of the rapid removal of waste sheets along the Hunter Valley.

What memories of ramifying fiord and warmly-tinted sandstone precipices raising themselves sheer out of the waterway for hundreds of feet, and etched with fantastic designs and shelters, are associated with journeys along the lower fifty miles of the Hawkesbury River, or with those conducted among the network of waterlanes and bays which spread from the main stream channel? Or along the upper stretches of the river, what sights awaits the explorer where the sandstone cliffs of the lower waterway slowly recede vertically until they form wondrous parapets two thousand feet above the stream, and over which streams take sheer flights into broad cañons occupied here and there by isolated hills capped by sandstone masses similar in character to those forming the ramparts of the enclosing valleys.

The Hawkesbury cañons are magnificent illustrations of differential erosion in horizontally-bedded rocks of Triassic age. The scheme of stream development in this region has been worked out by Professor David.*

A slope of small angular value has carried the late Tertiary peneplain from a height little above sea-level at Sydney to a position three thousand one hundred feet above the same datum at Lithgow, a distance of some sixty miles to the west Warping has caused marked local variations in the general level of the dome-like surface. The horizontal series composing the Triassic Beds in this region consist of an upper hard belt of sandstone and a series of lower and incoherent sandstones and shales. The tough sandstone has a maximum thickness of about nine hundred feet its eastern development is of harder nature than that to the west; and patches of shales occur throughout its mass. The underlying shales and softer sandstones form the Narrabeen Series, possessing a maximum thickness of about one thousand two hundred feet. The hard sandstone in the upper portions of the Hawkesbury forms ramparts to the main valleys and the minor ravines. The large valleys at times attain a width of many miles. All, however, are contracted to narrow gorges as they approach the main stream. The Kanimbla and Colo valleys are fine examples of this association of broad valleys and constricted outlets. The channel of the Hawkesbury below Wiseman's Ferry is less than half a mile in width and flows between perpendicular cliffs. The upper sandstone resists the forces of weathering, but is well provided with master-joints which allow of the ready percolation of water and admit of easy rupture, The underlying shales suffering deformation equally with the sandstones lie below sea-level in the neighbourhood of Sydney and the Hawkesbury River lower course, but outcrop at heights exceeding two thousand feet above sea-level in the Kanimbla and neighbouring valleys. Vertical corrasion produces deep narrow gashes in the dense sandstone cap and the incising streams discover the incoherent shales below. Their removal is easily effected, and the sandstone walls are left in overhanging positions. Loss of coherence is established and rapid recession of the cañon walls effected. The slope seawards of the sandstone causes its base to approach base-level near the points at which certain obsequent tributaries approach the main stream. Eastward of this point the underlying shales are not attacked owing to their position being below that of the watercourses. The result of such arrangement is at once apparent. The influence of corrasion is limited to an attack only on the hard sandstones, and the resistance of these durable beds to corrasion is exemplified in the constricted channels of the Nepean and Hawkesbury.

Earlier observers† of note perceived these curiosities of valley structure, and were at a loss to account for them. Later investigations‡ revealed the true character of the eroding agents.§

---

* T. W. E. David, Proc. R. Soc. N. S. Wales for 1896, xxx, pp. 32-70.

† Dana.
Darwin. Journal of a Voyage Round the World, 1891, pp. 413-416.

‡ T. W. E. David, *op. cit.*

§ For a fuller account of Blue Mountain geography reference may be made to—
J. E. Carne. Memoirs Geological Survey of N.S. Wales, No. 3, pp. 141-151

The disposition of the Hawkesbury and its tributaries suggests the presence originally of several small consequent streams, and their later capture by the development of the strong subsequent Hawkesbury. This strengthened the position of the main stream, and diverted the former consequent rivers in part into obsequent channels. The Nepean is either an obsequent stream, or one due to the original deformation.

This strikingly lengthwise course of the Hawkesbury above Wiseman's Ferry illustrates well the gradual growth of a stream by methods of piracy. A weak structure, viz., a fold, appears also to have influenced the subsequent direction of the stream. The lower consequent Hawkesbury, as also the harbours of Port Jackson and Botany Bay, afford criteria of late drowning for the coastal area.

Briefly, then, the study of New England rivers impresses upon the observer the durability of dense and coarse-grained acid plutonic masses, of inclined rhyolites, porphyries and siliceous slates, and of horizontally-bedded hard sandstones. The association of hard and soft structures horizontally disposed is seen to lead to wholesale reduction of the plateaux, owing to the incompetence of the hard overlying masses to withstand the undermining of the softer and inferior beds when once the corrading streams have sunk their way through the durable belts. The association of two hard belts of rock as basalt and underlying granite is seen to form excessively stable topographical forms, while the columnar structure of the principal basalt flows is observed to cause them to fall an easy prey to weathering when accompanied by softer underlying strata either vertically or horizontally bedded.

Above all, the wonderful development of broad lengthwise valleys and narrower crosswise valleys points to a complete harmonising of the stream courses with surrounding strata, a fact which in many instances also affords a criterion of revived drainage.

Discussion.

Palæontological, topographical, and structural criteria are indispensable to a correct understanding of the relative times involved in the production of land forms. In the investigation of successive base-level plains, the presence of fossiliferous shore-line deposits determines their position in time, and helps materially in differentiating between warped peneplains and degraded elevated surfaces when both belong to an old cycle of uplift.

Associated freshwater or æolian deposits also at times enable the age of the plain of erosion to be determined.

In the absence of old life forms, the evidence as to the geological age of associated peneplains is confined to that yielded by a knowledge of the rock structures of the district, the amount of elevation for each surface, the degree of

approximation to base-level for each, and the volume of material lost to each plateau by planation forces. In this connection, one must carefully take into consideration the importance of rock structure and composition. Faults, flexures, and joints assist materially in the work of degradation; the adjustment of streams to structure is attended by the occupation of anticlines and soft strata by lengthwise valleys, and of synclines by hills: the excavation of a V-shaped cañon in massive quartzites may occupy more time than that required for the production of a broad cañon in soft incoherent masses; the superimposition of hard horizontal strata over soft-yielding beds avails little against the onslaught of lateral corrasion succeeding to the establishment of a channel through the resistant layers by vertical corrasion, wholesale destruction of the hard layers then occurring through rapid removal of the softer beds.

Topographical features admit of explanation with a facility which bears an inverse ratio to their advance in age, since their ultimate fate is to suffer complete planation during the progress of successive cycles of erosion. With the progress of time, therefore, it becomes more difficult to correlate the old graded surfaces. Several circumstances may, however, be borne in mind when considering areas of approximately complete planation. Coextension of a surface, even when considerable variations in altitude occur throughout the area, point to the existence of one surface of planation only. Hills rising abruptly above an elevated undulating surface afford criteria of incomplete planation.

Ancient peneplains also may be correlated by the degree of dissection to which they have been subjected. In the case of sloping elevated surfaces occupying different levels on opposite sides of wide later valleys, the coincidence of one with the other may at times be demonstrated by continuing the surface slope across the intervening valleys. This coincidence of surfaces points to an old base-level plain tilted and subsequently maturely dissected.

In the New England area, the evidence as to the relative ages of the various cycles of activities is narrowed down to that afforded by a study of structure and erosion since the area has remained above sea-level since Triassic times. The greater portion, indeed, has existed as dry land since the commencement of the Permo-Carboniferous. Withal, there are several peneplains at various heights above sea-level, exhibiting wide differences in state of preservation. These being plateaux of erosion and not plains of accumulation, as revealed by a study of their surfaces, appear undoubtedly to be the result of subaerial denudation, and as such fall in completely with the ideas of the American physiographers.*

A brief mention of topographical conditions obtaining in New England during Palæozoic and Mesozoic times will assist materially in effecting an understanding of the evolution of the Tertiary and present surface features. It is a story of

* W. M. Davis.—Plains of Marine and Subaerial Denudation. Bull. Geol. Soc. America, Vol. VII, 1896, pp. 377-398.

successive periods of contemporaneous deposition, elevation, and plateau degradation. During the successive Palæozoic uplifts the continental area was pushed further northward, the present cordillera and contiguous areas indicating a region subject to repeated foldings, the thrusts probably coming from east to west. Extension longitudinally was accompanied by expansion in latitude, gain to the old land being affected by the elevation of latter deposits flanking the land formed during the previous cycles. Since the momentous Carboniferous period, New England proper has probably undergone no submergence by the sea.

Neither Cambrian nor Silurian strata are as yet proved to exist in the area under consideration.* Marine conditions doubtless obtained during the early Palæozoic. Both Lower and Upper Silurian strata exist immediately south of New England.

The Devonian Period was characterised in this region by extensive sedimentation. Certain of the beds prove the contiguity of land masses. Magnificent series of submarine volcanic tuffs occur containing radiolaria; and huge coral reefs are associated with these radiolarian tuffs. Lepidodendra are associated also with certain of the beds.†

For a distance of some hundred and fifty miles in a north-north-west and south-south-east direction (Warialda to Nundle), red jasperoid and manganese-stained strata occur in thick masses. These may also hereafter be found to have a Devonian age. The disposition of the beds near Tamworth, the occurrence of lepidodendra, and their association with large coral reefs, argues a gently subsiding area in which these deposits were formed, the sea being shallow.

The elevated land surfaces furnished, during a long cycle of denudation, a considerable proportion of the material composing the Devonian strata.

The gradual subsidence of the area of sedimentation and the elevation of the neighbouring land surfaces were disturbed at the close of the Devonian Period. Deformation occurred, although no actual junctions of Devonian and Carboniferous strata have been recorded from New South Wales. In other States, however, folding of the Devonian before the deposition of the Carboniferous on its upturned edges have been discovered. In New England, profound gaps occur in the palæontological record between Devonian and Carboniferous; the Gympie Beds themselves—of great thickness—also indicate the existence of a contemporaneous high mountain system. From these and other facts, folding of Devonian rocks in New England may be inferred prior to the formation of the Carboniferous. As a result of this deformation, the young plateaux of accumulation were attacked by subaerial agencies. Movements of subsidence more than once repeated accompanied the

* For a fuller discussion of the Palæozoic history, the reader should consult Procs. Linn. Soc. N. S. Wales, 1898 Presidential address by Prof. T. W. E. David.

† T. W. E. David and E. F. Pittman, Q.J.G.S., Vol. LV., 1899, pp. 16-37.

elevation of the central land area, and affected the coastal and shore regions. Long pronounced sedimentation ensued, vast accumulations of strata were formed, and periods of intense volcanism occurred from time to time.

In the New England district, the Carboniferous admits of separation into two very distinct divisions, an older known as the Gympie, and a younger, the Star Series. Widely varying conditions of deposition are shown by a study of these formations.

The former marks the formation of great slate beds, conglomerates, and tuffs; the latter of marine and fresh-water strata alternating with a wonderful series of dolerites, rhyolites, porphyries, and tuffs. A great proportion of the Star Series also consist of Rhacopteris claystones, impure coal seams, and conglomerates.

The laying down of the extensive beds of the Gympie formation was accompanied by the degradation of the great mountains of Devonian strata. As subsidence proceeded, the coastal portions of the degraded land surfaces disappeared beneath the encroaching sea and received caps of Carboniferous strata.

The removal of the mountains—the expression of probable early Carboniferous or late Devonian folding—by the forces of subaerial denudation was succeeded by widespread and pronounced earth-movements. The folding and crushing to which the inclined Devonian and horizontally-disposed Carboniferous strata were subjected was intense. From the present coast line—and, indeed, from points still farther east—to the far west, the evidence of this great crumpling survives in the rock flexures observable in the plateau of erosion. Magnificent examples of this rock contortion occur in the rocks of the Lower Macleay basin. This was, doubtless, the mighty mountain-making period of New England.* Probably the thrusts came from east to west. A section taken from Taree to Gunnedah would settle this question. The origin of this epeirogenic movement appears insufficiently explained by the degradation of early Carboniferous mountains and the consequent loading of offshore areas by the products of this gradation process. The mass of the Gympie sediments is negligible when compared with the mass of rocks affected by the mountain-making movement. The Carboniferous sediments themselves were also equally folded with the neighbouring land areas.

This far-reaching movement occurred at the close of the Gympie Period, that is, Gympie sedimentation was stopped by the deformation which produced the great mountain ranges of New England. The story of the succeeding Star Period reveals another great subsidence and subsequent folding on a large scale in the north and south portions of the area under discussion, but not so pronounced in its results as the late Gympie movement.

* The Gympie movement has been discussed by R. L. Jack for Queensland areas. Jack and Etheridge.—Geology of Queensland, pp. 72-123.

The extension of alternating acid and basic lavas (rhyolites, acid porphyries, and basalts) in prodigious quantities* was a marked feature in the Carboniferous Period as it had been in the Devonian† of more southern areas. The lavas were poured over a subsiding area, and tuffs containing numerous marine shells are sandwiched in with the lavas. The Devonian volcanic displays, on the other hand, were associated with numerous lepidodendra remains. The association of acid and basic lava sheets in an area of subsidence suggests a deep-seated origin for the volcanic displays due to overloading. Accidents of surface naturally modified the appearance of the lava sheets.

Adverting to the discussion of the mountain-making inaugurated by the Gympie thrusts, it may be mentioned that, these forces once incepted, their duration was long continued. The whole tenor of the facts, as ascertained by a study of the granites and the foldings, points to early movements of crumpling whose force slackened but did not cease throughout the Star Period, at whose close a revival of the folding occurred. Criteria of this continued movement are the repeated granite and other acid plutonic intrusions into the folded Carboniferous rocks and into one another. Along the lines of maximum weakness the plutonic masses forced themselves. These positions of least resistance are located in New England, now, however, as a result of the strengthening by the granite intrusions, the most stable portion of the folded area. Huge apophyses and dykes would be given off by the bosses and laccolitic (?) masses, which would, in many cases, reach out feelers to the old land surface. Associated with the plutonic masses are great belts of old porphyries, mostly of acid types.

On so vast a scale were these intrusions, that the acid masses of deep-seated consolidation, now exposed at the surface by later erosion, occupy thousands of square miles of surface.

Among the many varieties of granite of varying age in New England, two stand out conspicuously. One is an older fine-grained and greatly-metamorphosed rock occurring in the northern half of the area; the other a more basic variety, coarsely porphyritic in character, intrusive, and containing notable percentages of such minerals as hornblende, biotite, plagioclase, ilmenite, magnetite, and sphene.

From a study of the old planed surfaces, one is led to postulate an immense mountain system for late Carboniferous and again early Permo-Carboniferous times, comparable, doubtless, in size with the modern Andes or Himalaya. Yet, between its formation and the laying down of the Upper Marine Series of the Permo-Carboniferous, the untrained mind is almost overwhelmed in the contemplation of the time involved in bringing about such a profound topographical revolution as is indicated by certain unconformabilities to be seen in various portions of New England and the associated areas.

* J. B. Jaquet.—Iron Ore Deposits of N. S. Wales. Mem. Geol. Survey, No. 2, pp. 69–71.
† E. C. Andrews.—Report on the Yalwal Gold-field. Mineral Resources N. S. Wales, No. 9, pp. 14–27.

At Yalwal, Upper Marine conglomerates lie on the undulating surfaces of Carboniferous granites and Devonian strata. The unconformability is marked.*

The Devonian strata are much crumpled, and their bevelled-off edges terminate abruptly against a fairly smooth surface, into the irregularities of which the horizontally-bedded conglomerates fit exactly.

The researches of J. E. Carne,† Assistant Government Geologist, have revealed the presence of similar phenomena at the bases of the Blue Mountain valleys, where Permo-Carboniferous and Triassic strata of gentle slope overlie subdued Carboniferous granite and Devonian surfaces.

In the Clarence River basin, strata of Permo-Carboniferous age contain granite conglomerates, the oldest of the granites being probably referable to the Carboniferous.

The reduction of these vast areas of relief must thus have been brought about before the deposition of the Upper Marine, or even the Greta Coal Measures. The capping of Carboniferous strata overlying the granite masses was first attacked, and many thousands of feet of the stratified rocks had to be removed before the deeper-seated varieties were exposed. Then followed their reduction in turn. Yet this planation was so nearly accomplished that extensive regions of very moderate relief were induced in the granite areas. There appears to be no reason to assign forces other than those of subaerial denudation in the accompliahment of this task. The removal of the Himalayas by the forces of erosion would probably occupy no greater a period of time than that occupied in the reduction of these early Australian Alps to form the Permo-Carboniferous deposits.

Subjugation of the mountains, however, does not appear to have been complete at the close of the Permo-Carboniferous. The granite and other old land surfaces, overlaid unconformably by the Upper Marine, represent the old coastal areas, and therefore the portions most likely to have suffered complete planation during the grading process. These coastal areas are, however, diversified by dome-shaped hills rising for hundreds of feet above the valleys. The central portions suffered less, and contained numerous large elevations, all, however, belonging to the class of "subdued mountains." The gentle elevation of the central highlands, which was contemporaneous with the coastal and shore subsidence, also assisted in preserving the relief of the mountains.

The importance of this Permo-Carboniferous erosion of a lofty mountain chain having a granitic core cannot be over-estimated in discussing the sequence of geological events in that and succeeding periods. For example, the barren nature of the majority of late Permo-Carboniferous, the Triassic, and Cretaceous rocks is explained by the erosion of granitic massifs, whereas the fertility of a great portion of the Carboniferous area is due to the presence of extensive series of dolerites and basic tuffs.

* E. C. Andrews.—Report on Yalwal Gold-field. Mineral Resources, No. 9, Diagram on p. 17.
† J. E. Carne.—Kerosene Shale Deposits of N. S. Wales.

The Permo-Carboniferous period itself admits of grouping into several divisions. The early stages consisted of a subsidence for the coastal areas, and a rapid demolition of the immense highlands of New England. Many thousands of feet of Marine strata were deposited, which express in some measure the loss sustained by the rising plateau. Intensely cold periods are indicated for this division of the Permo-Carboniferous, known as the Lower Marine; and doubtless the presence of the great mountain ranges accentuated these Arctic conditions.

More stable conditions of equilibrium supervened, and great marshes and lakes occurred on the site of the Lower Marine beds, and furnished vegetable tangles which were destined to form the thick Greta coal seams.

Rapid subsidence, with further inland elevation, succeeded to the marsh period. The granite core was still more exposed, and in places actually formed a base for the strata of this period. This is known as the Upper Marine division. Some five thousand feet of strata were deposited, and represented further loss to the adjacent region of relief. Still, however, the mountain system was considerable. Yet another great cold period occurred in this time.

With the close of the Upper Marine, other long periods of more stable equilibrium occurred, and extensive deposits of coal and kerosene shale resulted.

Subsequently a differential movement caused great gain to New England, and ushered in a new condition of things. This movement was not on a scale at all approaching the magnitude of the forces which formed the Australian Alps of late Carboniferous time. Long-continued forces produced gentle folds in the recently-bedded strata and brought to light many thousands of square miles of Permo-Carboniferous rocks. More pronounced local earth-movements affected certain districts. Among these may be mentioned the repetition of granite intrusions into rocks of Permo-Carboniferous age, occurring in the Clarence River basin. Contortion and induration of the slates followed. Gold and silver lodes were developed in the rocks of Tooloom, Rivertree, Drake, and Boorook as the result of such action. Coal seams belonging to this period were also altered into graphite by the intruding granites.*

Since this pre-Mesozoic movement, the greater portion of New England has remained above sea-level.

The deformation which led to the formation of the early Mesozoic strata caused the rapid subsidence of areas now partly incorporated in extreme northern New England and regions contiguous thereto; for example, portions of the Blue Mountains, Capertee, Dubbo, Mudgee, and Warialda districts, and the Clarence River and Darling Downs regions.

* E. C. Andrews.—Ann. Rept. Dept. Mines for 1901, p. 170.

The differential movement producing the Mesozoic troughs effected an elevation of New England simultaneously with the subsidence of the adjacent areas. A great revival of stream action was set up. The old land now revealed an undulating plateau composed in great measure of granite, the reduction of which yielded great quantities of arkose and coarse barren sandstone beds. Conglomerates, volcanic tuffs and basic lavas are of frequent occurrence, especially in the Clarence and Richmond River basins and the Darling Downs. Important coal seams also were laid down.

The typical sandstones of this earlier Mesozoic period are coarsely-grained. The grains are partially rounded, current bedding is exceptionally well marked, and plant remains are very frequent. Large areas of fine shales alternate with coarser beds, and also occupy spaces in the sandstone. Fish remains and bones of large labyrinthodont animals occur in the strata.

The thick conglomerate masses have a greater development in the north-east, the shales a more extensive distribution in the areas south of New England.

No evidence of undoubted marine conditions exist. On the other hand, fresh-water remains are plentiful. Marshes, shallow water areas, and strong running streams bearing along huge loads of *débris* were numerous. Large portions of the subsiding area must often have been exposed to the air. Large rivers, deriving their loads from all sides of the basin, entered the area and wandered here and there discharging their burdens. Deep-water conditions obtained in some portions removed from the conglomerates. In these the finest silt was deposited.

An enormous period of denudation is shown for the Triassic. Unconformable junctions may be studied in many portions of the basins. The coast of the period extended beyond its present limits to the east.

An examination of the Triassic coast lines reveals a rapid subsidence in places, hills being buried quickly under masses of conglomerates and sand, the forces of erosion not being allowed to plane off these features.

The Cretaceous was ushered in by a very mild and almost uniform elevation of the coastal area. This movement was pronounced enough to convert the Triassic measures into dry land, but at the same time so slight that the newly-formed dry land, which has suffered erosion since early Cretaceous time, shows only to the trained observer the marks of the bevelling process of late denudation. At first sight surface appears to coincide with structure. Careful examination reveals the planing off of slightly bent layers. Possibly this small slope may have carried the old worn-down surface as much as one thousand feet above sea-level in its central or most elevated portions. Concomitantly with the general elevation of the upland, the western and eastern regions underwent subsidence. These marine conditions never extended to New England or the present associated coast. Huge masses of

strata were accumulated in an extensive shallow sea, to form, during later elevations, the shales, sandstones of the Rolling Downs and Desert Sandstone formations, and much of the material for the "artesian beds."

The immense mountain system of early Permo-Carboniferous times, which had been in great measure subdued by the cycle of denudation at the close of the Palæozoic, re-formed in early Mesozoic times, and still more reduced during the progression of the Trias and Jura, had its topography accentuated once more by the Cretaceous deformation.

The Cretaceous history of the uplands is a story of their almost complete reduction to base-level.

Two cycles of erosion are indicated for the Cretaceous. Both reduced the land surfaces almost to sea-level. The earlier denudation resulted in the development of the Bolivia Plain (frontispiece), above which residuals from the Jurassic still exist. Another cycle was inaugurated by a further uplift of about five hundred feet, and the Mole peneplain was formed. This second reduction may possibly represent the Upper Cretaceous erosion. Other oscillations of level doubtless occurred. With each uplift and corresponding gradation period, the approximately domo-shaped granite core was more exposed and caused to occupy an ever-increasing percentage of the land surface.

At the conclusion of the Cretaceous denudation the valleys had been broadened, and the forces of lateral corrasion had again and again attacked the residual mountains of the area during the periodical wanderings of the sluggish streams from side to side of their wide valleys.

An adjustment of streams to structure ensued, the softer parts of the metamorphic complex having long since been removed. The monotony of the extensive plain was at the close of the cycle only broken by certain granite and hard slate hills which stood out as monuments of resistance. These were handed on "as inheritances" to the next succeeding cycle.

Residuals of the Cretaceous uplands include the summits of the hard granite masses of the Snowy Mountains at Guy Fawkes, the plutonic masses of the Barrington Tops (five thousand feet above sea-level), and the higher points rising above the general level of the summits of the Bolivia and Deepwater Mountains.

The rivers had reached the stage of extreme old age. Only such pebbles as consisted of the most indestructible material could exist along the watercourses during the final stages in base levelling, while all softer rocks had, during the cycle, been reduced by corrasion to the finest degree of comminution, and carried into the contiguous oceanic area.

From the nature of the old complex these Cretaceous pebbles would most likely consist of well-rounded quartz, tourmalines, zircons, sapphires, topaz, emeralds, and similar minerals. Gold also would be preserved by reason of its weight and toughness. The shores of the Cretaceous sea into which these rivers emptied themselves to the west were in the neighbourhood of Moree, Narrabri, Gunnedah, and Yetman. To the north marine conditions obtained. The eastern shores of the New England area extended beyond their present limits.

The almost complete reduction of a vast area of rocks possessing such great obduracy to erosion as the Palæozoic rocks of New England involved long-continued subjection to the forces of weathering, corrasion, and transportation. So dense and indurated are certain of the siliceous slates of Permo-Carboniferous or Carboniferous age forming the eastern aspect of the plateau, that large streams like the Clarence, having broad valleys along certain portions of their head-waters, are, lower down their courses, forced to flow through narrow gorges, three thousand feet deep, excavated in almost crystalline slates. Yet three thousand feet to three thousand five hundred feet above the stream the mountains rise almost to a common level, showing how the forces of planation had in Cretaceous time accomplished their purpose. The removal of material during these geographical cycles probably led to the continued gentle subsidence of the eastern and western basins, and the unloading of the area which had formerly been one of great topographical relief prepared the way for the Tertiary uplifts and displays of volcanism in the New England area.

The Tertiary Period.

This slight digression into Palæozoic and Mesozoic history is necessary to understand the succeeding and final steps in the sculpturing process.

Adverting to the main consideration, viz., Tertiary and recent revolutions in New England topography, one observes the close of the Cretaceous to have been attended by pronounced and widely extended elevation of the Mole Plain. The movement was, however, differential. The study of the elevated Triassic beds suggests that the decided movement of upheaval was restricted in area, forming a dome-shaped area with minor warpings over the New England district proper, and extending eastwards to embrace the area now drained by the mountain tracks of the present streams. Over the present coastal area the dome was probably flattened. The maximum folding occurred at a series of points (longitudinally considered) intermediate to the coastal and table-land areas. The mild cañons of the undivided table-land itself and the profound V-shaped gorges into which they empty themselves is a proof of this differential movement. A great part of the Jurassic sandstones of the Clarence basin show evidence of slight uplift only. An elevation of about one thousand feet was set up at Tenterfield, Glen Innes, Armidale, Hillgrove, Wooloomumbi, Uralla, Walcha, and other localities.

In the district immediately south of New England, viz., the Blue Mountains, the Triassic sandstones probably experienced a slighter uplift than this. A measure of the amount of this elevation could be obtained by continuing the slopes of the strata on both sides of the centre of uplift, though the amount of erosion so indicated would include the Cretaceous denudation also.

The consequent streams which for ages had held sluggish courses east and west of the low Cretaceous divide were revived on the disturbance of the hydrographic system, and, flowing swiftly, incised themselves into the surface of the gently-inclined dome. An approximation to river grade was next reached by the main watercourses. From the graded stage lateral corrasion worked so as to widen the valleys until the streams flowed in broad basins. When these basins had been further developed to plains approximately at sea-level, a great display of volcanic activity was brought about.

Palæontological criteria of the age of this period of volcanism are extremely rare and uncertain, being confined to the evidence yielded by plants contained in the old fluviatile deposits buried beneath the lava floods. The old consequent streams, now deflected from their channels, established themselves afresh upon the cooling lava sheets or took up fresh directions on the contiguous granite and slate slopes. The base-levelling action of the streams was continued, but was interrupted from time to time by additional basic outpourings. Many distinct flows resulted from this basic visitation, each having its characteristic structure and composition, and being marked off from preceding flows by tuff beds or ropy and slaggy surfaces. Craters are characteristically absent; doubtless the lava floods were extruded by means of fissures, which same vents are now plugged up by dykes. An older visitation still is marked by a series of flat-topped and conical basalt hills rising to a general height of from five thousand to five thousand two hundred feet above sea-level. Ben Lomond, Hittarn, Chandler's Peak, and Big Duval represent several of these residuals in higher New England. These all rise from a flat surface many miles in extent, four thousand three hundred to four thousand five hundred feet above sea-level, and are composed of vesicular olivine basalt.

A great period of erosion is thus shown between the two periods of volcanic activity, the first of which produced a plateau, the remnants of which are now widely removed from each other, and the fiery floods which produced the present flat of higher New England. A possible explanation, however, of the four thousand three hundred and four thousand five hundred feet levels is that afforded by the differential erosion of a series of lava flows belonging to one period, the four thousand three hundred level being determined by resistant basalt layers. The evidence, however, goes to prove two lava visitations, one in the earlier, the other in the middle or late middle Tertiary period.

After the last considerable outburst in Tertiary time, the formation of the Sandon and Stannifer plateaux was effected. The watercourses, which flowed in broad basins after incising their courses in the Cretaceous peneplains and had been buried subsequently beneath the lava floods, now stand out above the Tertiary peneplain. The mantle of protection thrown over these old river-beds by the basalt has allowed of their preservation during the reduction of the associated areas to still lower levels. At Uralla (Pl. XXXIII, fig. 2), Walcha, Tia, and the neighbourhood of Niangala basalt-capped drift occurs in places as much as from one hundred to two hundred feet above the level of the Sandon peneplain, while at Deepwater, Hillgrove, Armidale, and other New England localities the old river drift is found practically at the level of the surrounding plain, the covering basalt forming more or less isolated points.

From a study of these buried rivers it is possible to understand in great measure the stage of development attained by the rivers prior to the period of maximum Tertiary volcanic activity.

The old streams belong to at least two distinct periods of fluviatile action, one much younger than the other. Both are overlain by basalt. The following notes refer to those of the earlier period.

In New England, as also in Monaro and the high level plains of Victoria, the drift of fluviatile origin is very extensive. In the former locality these large and important deposits occur either on or slightly elevated above the Stannifer and Sandon peneplains. In the neighbourhood of Mudgee, in Monaro, and Victoria they occupy similar positions, although in certain cases there appear to be signs of pronounced differential movement in Monaro, owing, probably, to faulting or strong folding subsequently to the general upheaval, which thus places certain of the "leads" at very different levels.

In the majority of these deposits a distinct channel excavated in the older rocks may be discerned, which, however, does not always contain the whole mass of the river wash, this generally overlapping the enclosing walls (known as "rim" rock) and spreading out on each side for great distances. Often the "gutter" or deepest channel is some fifty yards in width and occupied by well-rounded gravel.

The overlying beds of fluviatile material overlap until they fill the original cañon excavated in the plain. The cañon being filled, the beds are seen to spread away on each side of the "rim" rock.

These observations point to a different set of conditions obtaining at present along the lower courses of the coastal streams where the original channel is widened by the process of lateral corrasion, enormous flood plains occupying the bases of the flat-bottomed valleys, all traces of well-defined narrow "gutters" having vanished long since.

An examination of these fluviatile deposits reveals a series of widely different deposits.

The thickest masses generally occur in areas south of New England, as in Monaro,* Victoria, the Shoalhaven, and Bathurst districts.

The base consists for the most part of well-rounded gravel occupying a defined channel or gutter. In the older deposits quartz pebbles† constitute the bulk of this material. Their size, as also their stage of sphericity, is variable. Associated with them are zircons, sapphires, spinels, rubies, garnets, tinstone, ilmenite, and other products presenting great obduracy of resistance to the forces of attrition. These basal gravels are frequently auriferous.

Thick clay and sand bands overlie the auriferous gravels. Lignite beds are also not uncommon sandwiched in with the clay and sand seams. In Upper Monaro the writer has observed as many as three successive lignite or carbonaceous clay layers in one "deep lead" section. The maximum thickness observed for the lignite was thirty feet. Cross or diagonal bedding is an exceedingly common feature in the coarse sandy layers. In many cases the grains are angular and subangular.

At Walcha, in New England, three thousand five hundred feet above sea-level a bed of lignite occurs overlaying basalt. The bed consists entirely in places of matted tree trunks and branches.

The uppermost masses at times exceed half a mile in width. Extensive deposits at times are found close together, evidencing the flat nature of the country immediately preceding the basaltic inundation.

Another fact worthy of observation is the pronounced dips observable in many of the channels. Especially is this marked in certain of the Monaro, Vegetable Creek, and southern New England examples.

The philosophy of these observations appears to be much as follows:—

The occurrence of the leads on or slightly removed only above the broad Sandon and Stannifer plains, as also on corresponding levels in southern areas, shows that the land had been worn down to the peneplain stage, and that these large rivers now buried under huge lava floods at elevations exceeding three thousand feet formerly wandered sluggishly across plains not much removed above sea-level.

The slight elevation of certain portions of the leads with respect to the surrounding plateau points to a still closer approximation of the country to base level before the great Tertiary uplift but subsequent to the lava outbursts.

The occurrence of well-defined channels in these old well-graded surfaces, and the presence in the same of well-rounded wash often consisting only of such resistant material to the forces of abrasion as quartz and gemstones, points to a slight oscilla-

* E. C. Andrews.—Report on Kiandra Gold-field. Min. Resources, No. 10.
† T. W. E. David.—Report on Vegetable Creek Tin-field. Mem. Geol Survey N. S. Wales, No. 1.

tion of level after the forces of erosion had reduced the later Cretaceous plateau to a series of gently undulating surfaces. The slight elevation gained by this variable elevation gave river action a decided impetus. The streams which had meandered across the reduced surfaces in broad flood plains now proceeded to quickly wash away the incoherent alluvial plains, and to excavate channels in the hard underlying rock. Into these, by intermittent rains, the well-rounded pebbles—the survival of the fittest—from the Cretaceous plateau were swept.

This stage was, however, of short duration. The streams had barely incised themselves into the tilted surface when other vibrations of level supervened. The gravel period was suspended. Sand and clay bands were deposited. Yet less stream grade was shown at later periods, and the aggrading process became correspondingly pronounced. The sand and clay making periods gave place to the formation of lignite beds. The streams now had spread out in places into lakelet form. This shows an almost complete reduction of grade. Yet this condition may be traced for distances along the stream courses for many miles. These periods of sand, clay, and lignite formation were repeated several times, especially in southern areas.

The final stages in many cases evidence the presence of quiet lagoons and great weathering of the rocks composing the surrounding country.

The large bodies of auriferous gravel occupying the channels, as also the great thickness of the overlying masses of sand, point probably to intermittent heavy rains rather than to a regularly wet climate.

The pronounced grades obtaining at present in many of the "lead" channels are due to the great Pliocene (?) deformation, modified to a slight extent by subsequent oscillations, and possibly also to faults occasioned by the deformation.

Possibly from fifty to seventy-five per cent. of New England was submerged by these lava inundations. Despite the constant attack of the agents of erosion during the formation of the Sandon and Stannifer plateaux and the revived energies of the stream of Post-Pliocene times following on an uplift of three thousand three hundred feet, immense masses still exist to attest to the former coextension of various now isolated flows. Especially marked in point of area are the flows around the Nandewar Ranges, the Hunter River basin, the Manning and Hastings head waters, and the Glen Innes district. Continuous flows must have existed having areas of several thousands of square miles.

Relying on topographical forms to furnish the age of the latter Tertiary basalts since palæontological criteria are untrustworthy, being confined to leaves of plants, which, although having no counterpart in the present New England flora, yet are almost indistinguishable from leaves of trees in present coastal "brush" areas,* we find that the ground we stand on is not altogether unsound. In the first

* H. Deane.—Presidential Address, Proc. Linn. Soc., N. S. Wales, X, p. 655.

place, the great centres of the disturbances, as far as New England is concerned, are to be found at Guy Fawkes, the Guyra plain, and the Walcha-Hanging Rock district. In the Guyra plain area numerous natural sections reveal the presence of the Palæozoic rocks at heights approximating to four thousand feet. Those in the direction of Glen Innes and Armidale gradually decrease, so that the lavas are seen to have occupied a mountainous region, fairly level on top, but sloping away to the north and south to much lower levels. By following the hill slopes leading from the Guyra peneplain to the Sandon and Stannifer plains, one observes that the basalt has suffered extensive denudation. The basalt is also observed to have thinned out considerably in certain directions until it merely formed a capping to the late Tertiary stream deposits. (Pl. XXXIII, fig. 2.) Evidence of similar action may be observed in the Guy Fawkes and Walcha districts.

We thus see that the Cretaceous peneplain (Mole plain) had advanced to old age as regards dissection before the great Tertiary lava outflows, and that the maximum effort of the basalt demonstrations was located in the less reduced portions of the late Cretaceous plain—in fact, that the lavas inundated the mountain region. Yet so far removed were the displays in point of time from the late Tertiary uplift that the plateau, rebuilt in great measure by these igneous floods, had suffered wholesale degradation between the period of volcanicity and of Pliocene (?) elevation, and also that the Sandon and Stannifer plains have been reduced considerably in height over wide areas since the lava visitations, and this, too, at a stage in plain development when subaerial forces were much reduced in competency.

We see, then, that the basalt period of greatest intensity must be advanced far into the Tertiary Period, as evidenced by the reduction of the later Cretaceous peneplain, and yet carried back a considerable distance from the Pliocene (?) uplift. The writer would feel inclined thus, on topographical grounds alone, to assign a middle or late middle Tertiary age for the great basalt display.

What the age of the earlier demonstration is, if indeed there was an earlier one, is doubtful. Certainly it is Post-Cretaceous, since it overlies residuals of the Sandon and Stannifer plains alone.

An interesting fact is the selection of the unakas or large mountain masses on the partly reduced Cretaceous plain by the basic lavas over which to pour their extensive floods, leaving the less resistant plains uncovered in many places. It may, however, be mentioned that the dense resistant granite masses of northern New England escaped the basalt deluges altogether.

Marked variations in structure and degree of basicity are evidenced by a study of the flows. Around Ben Lomond, Guyra, Llangothlin, and Duval they consist mostly of dense vesicular lavas, with more or less perfectly developed columnar structure. (Pl. XXXIII, fig. 1.) Olivine is a common constituent, while flow structure

is noticeable in the rock fragments found on the flattened hills of the district. Basaltic structure is, perhaps, best studied at Guy Fawkes. The almost inaccessible escarpment of Point Look-out is composed of basalt, arranged in four or five tiers aggregating more than one thousand five hundred feet in thickness, and showing magnificent columnar structure. The Upper Ebor Falls occupy a small amphitheatre determined by the unequal recession of the vertical basalt columns. (See fuller description, *ante* pp. 173–174.) This semicircular space overlooks a much larger amphitheatre excavated in various basalt flows by the retreat of the Guy Fawkes River towards the plateau.

The top of the Ebor Falls is about four thousand feet above sea-level. Beyond this the surface rises in a series of approximations to terraces to the five thousand feet level. Several of the terraces are associated with different lava sheets. This step-like structure is probably due in part to an unequal recession of the hill slopes during late Tertiary erosion. At the Hunter and Manning River head waters two distinct basaltic types occur, one a holocrystalline rock with large augite crystals so abundantly scattered throughout its mass as to obtain for it locally the name of "plum-pudding stone." Other types found here are dense fine-grained, vesicular olivine basalts.

An enormous period of time was taken up in the development of the Stannifer and Sandon plateaux out of the resistant Palæozoic rock and Tertiary basalts In New England proper this represents at least the removal of a rock mass from one thousand to one thousand five hundred feet in thickness and several (?) thousands square miles in extent.

Stanthorpe, Wilson's Downfall, Tenterfield, the Mole Table-land, Deepwater, and Glen Innes are located on the Stannifer, while Armidale, Hillgrove, Uralla, Woolbrook, and Walcha are situated on the Sandon peneplain. The plain located by these towns, however, represents but a fraction of the area originally occupied by the Tertiary peneplain. Eastwards its former extension is marked by long ridges and flat-topped mountains winding in and out like streams for many miles, but all rising to the same general level.

The Stannifer and Sandon peneplains mark gradations periods of less duration in time than the Cretaceous plains. Whereas few irregularities broke the general evenness of the great Mole base-level plain at the close of the Cretaceous Period, the Tertiary surface developed at the expense of the Cretaceous levels is interrupted by great residual masses which almost isolate the Stannifer from the Sandon peneplain. East of Glen Innes the "Mole Plain" residuals are also enormous.

The Tertiary basalt flows, however, increased the task of the Tertiary rivers, and lengthened the gradation period. Numerous monadnocks lie scattered over the Tertiary surface, while the term unakas proposed by Hayes* to represent large

* C. W. Hayes.—The Geology of the Chattanooga district.

unconquered mountain masses may be applied to the Bolivia Mountains, the higher New England platform, and the mountains south of Walcha and between the Manning and Hunter Rivers. Many of the smaller residuals consist of basalt-capped deep leads. Towards the close of this cycle of erosion the scenery consisted of several enormous peneplains, approximately at sea-level, coextensive indeed, although almost isolated in one or two places by ranges of hard Palæozoic rocks. These highlands were from one thousand to two thousand feet above the surrounding plain, and approximately also the sea.

In the south, basalt-capped hills surrounded the Sandon plain, while to the north the Stannifer level was mostly hemmed in by bold granitic masses. These unreduced masses mark the residuals of the Bolivia and Mole plains, as also the flat-topped basalt mountains of the Guyra level.

The great cycle of elevation for New England and the Blue Mountains was started in late Tertiary time. The Stannifer, Sandon, and correlated plains were upraised in form of a huge flattened dome, or rather raised bodily as to their central portions and flexed on their eastern and western flanks, so as to assume roughly the surface of a solid contained between two planes of a flattened cylinder, their longer axes being coincident with that of the cylinder. The folding is more pronounced on the eastern than the western side of the plateau. The general uplift was three thousand three hundred feet; but many deformations occurred which modified the general height. Some of these warpings were contemporaneous with, others followed, the general movement.

Armidale, Tenterfield, Deepwater, Glen Innes, Hillgrove, Wooloomumbi, Uralla, Walcha, Walcha Road, Woolbrook, Enmore, and Tia mark the three thousand three hundred level. East of Glen Innes, however, the plain is found to rise gradually to the four thousand feet level for many miles with same undulating surface. Glen Elgin, Gibraltar, Bald Nob, and the plateau cut up by the Mitchell and Little Rivers mark portions of this deformation. The deep black-soil flats at Stonehenge, Glen Innes, &c., appear to be aggradation plains due to deformation. Stanthorpe and the Darling Downs represent deformation to the north by which the three thousand three hundred level gradually passed through heights of three thousand, two thousand nine hundred, one thousand five hundred, one thousand nine hundred, and two thousand feet, the surface all being undulating and coextensive, with rough mountains occupying intervening spaces. The granite and slate plateau so wonderfully cañoned by the various South Clarence streams suddenly ceases, and gives place eastwards to the horizontally-bedded Jurassic measures. Strong conglomerates abut against the dense indurated Palæozoic rocks, and in places show pronounced easterly dips. The Jurassic rock surfaces are at considerably lower levels than the contiguous slate and granite plateau. A flexure is here probably present. Thence seawards the Clarence series maintain an almost uniform gradually decreasing level.

The Emmaville (two thousand nine hundred feet) plains may represent slight deformation, or the beginning of the western limb of the fold. Several other areas of warping probably exist on the eastern and western slopes of New England.

South of the New England area, however, deformation may be well studied among the approximately horizontal beds of Triassic sandstone. Here the general surface derived from degradation of the sandstones in early Tertiary times is seen to present great variations in level. In almost every case the warp slopes are of small angular value, yet differences in level become pronounced when the angle of inclination perseveres over considerable distances. Thus, the Hawkesbury sandstone, with a maximum thickness of about one thousand feet, has its summit three hundred feet above sea-level at Sydney Heads; seven hundred feet at Peat's Ferry, thirty miles north of Sydney; seven hundred feet at Wiseman's Ferry; seven hundred feet at Port Hacking, fifteen miles south of Sydney; two thousand feet at Kiama, fifty miles south; two thousand two hundred feet at Moss Vale; one thousand two hundred feet at Springwood, forty-five miles west; and three thousand six hundred feet at Mount Clarence. Here, then, we have evidence of a decided warp, with Sydney occupying approximately the lowest point. Before the Pliocene uplift of the Triassic, when the great Tertiary denudation had reduced the Hawkesbury sandstone elevations, the height of which had expressed the amount of upheaval in early Tertiary time, to sea-level, leaving small residuals only to mark the older rocks, the surface coincided only approximately with the structure. Instead of being a series of horizontal layers, the surface represented a very oblique bevelling-off of these beds. Thus the age of the rocks forming the general platform of Katoomba, Blackheath, and Mount Victoria is probably older than those of the sandstone rocks about Sydney. This, however, would not accentuate the amount of warping, but simply show a discrepancy in age of the strata.

One of the most convincing proofs of differential elevation east and west is shown by the present aspect of the watercourses. The streams of the plateau proper have cut shallow basins only in the general level, attaining on their eastern limits a depth of about two hundred feet. These in turn empty their contents into deep cañons, as much as three thousand feet deep, by means of gigantic waterfalls. The deep cañons are seen to be excavated from the same flexed surface. This evidences an exceedingly mild fold for the central area and a decided fold at a point intermediate with the coast, for the effect of running water has been to excavate the deep cañons to the east while the central plateau underwent slight roughening only.

With the great elevation came the revival of the consequent Tertiary streams. Across the lines of maximum folding these contour streams set up a cascading action. Deep V-shaped gorges (Pl. XXXVII, fig. 1) became the early expression of these forces, and contemporaneously with their recession the revived rivers entrenched

themselves in shallow valleys along their old broad basins. Great gaps in the ranges, like that by which the Macleay passes through the Snowy Mountains to the coastal area and three thousand feet in depth near Carrai and Kunderang, point to the cutting action of the stream as the anticline rose athwart its course. While yet these consequent streams were in their youth, subsequent streams quickly carved trenches for themselves in the softer and approximately meridionally-disposed slates. The depths to which these streams were corraded were always determined by that of the main channel. As head-water corrasion proceeded, and allowed of the deeper trenching of the uplands by subsequent streams, many of the smaller consequent rivers were captured as to their head waters, the portions diverted backwards being known as obsequent or reversed streams. Examples of this appear to have occurred in the basin of the Macleay. During the previous cycle of erosion, the Macleay basin had been enlarged at the expense of both smaller eastern consequent streams and of the head waters of the ancient Gwydir, flowing westward. During the Pliocene uplift, the Macleay held its ground and enlarged its subsequent tributaries at the expense of neighbouring streams. As the plateau became trenched on both sides by head-water corrasion, an approximation to base-level was reached by the young streams, and aggradation flats were formed, only to be removed as the river cut its way deeper into the rock masses. Where columnar basalt overlying friable or soluble rocks, as along some branches of the Hunter, Macleay, Clarence, and Peel Rivers, opposed the corrasive action of the young streams, degradation proceeded along rapid lines, broad valleys with bordering precipices in such cases being associated with the rivers. Columnar basalt overlying softer strata, as also the vertical slate, forms great basins in which landslips are common, millions of tons of rock settling down into the ravines. Their destruction is rapidly effected by the cascading waters, which passing down the mountain tracks carries the material so obtained lower down to the valley tracks to form plains.

The Peel and Gwydir, along parts of their courses, show the various relations of erodibility to rock structure and composition. Here very broad valleys occur in the soft inclined Carboniferous tuffs, separated by high precipitous peaks of hard rock capped at times by basalt. Along the Clarence the broad valleys of the upper portions of the river (where weak structures abound) are often observed to give place to narrow cañons along the lower portion of the watercourses where indurated slate and sandstone belts are encountered. Examples of this occur in the slates along the Mitchell River, and near Copmanhurst in the sandstones for the main Clarence River.

In the granite the younger streams are generally confined, but open out into fairly broad valleys a little lower down. Here the sides are usually bold and almost inaccessible. In the ordinary fissile slates the young valleys are excessively steep and profound. The winter sun rarely penetrates their gloomy abysses, while

tremendous knife-edged precipices form inaccessible walls above the waterways. At the Apsley Gorge, recession of the waterfall is said to have taken place to the extent of over fifty yards during the last fifty years.

In dense hard sandstone, like that in the neighbourhood of Sydney, erosion was reduced to a minimum. Here, since the grand uplift, corrasion has been limited to the excavation of narrow cañons. Higher up the tributaries of the Hawkesbury, however, the association of hard sandstone with soft strata has led to the formation of enormously wide valleys. Where the massive sandstone ramps overlaid soft shales, recession of the cliff walls proceeded with extraordinary rapidity. The instability of the underlying strata led to the undermining of the compact overlying rocks, which yielded along their master-joints, and sent masses, thousands of tons in weight, crashing into the valleys below. The slope of the plateau, *i.e.*, of the strata—for here the bedding planes of the sandstone and the Tertiary surface of erosion practically coincide—caused the sandstone a few miles to the eastwards to sweep down across the base of the main valley, at a point near the base-level of erosion. Instantly the influence of rock structure and composition becomes apparent, the gorge narrows, the streams draining the broad cañons of the upper tributaries pass quietly between great precipices, thence through defiles to the sea. Every fragment of the material formerly occupying the site of the broad upper cañons has had to pass through the narrows of the lower stream.

As the valleys incised themselves in the eastern aspect of the plateau, the land surface experienced the preservative action of the dense vegetation. Short courses and heavy rainfalls made for rapid degradation of the coastal plateau, but as the forces of vertical corrasion began to trench the eastern upland into blocks, the rich soil became clad with a dense mantle of "brush" (jungle).

The effect of this was that corrasion and transportation were reduced considerably, although weathering was accelerated. Lateral corrasion in the valley tracks widened the valleys but slowly, and even in time of heavy rain many of the head streams are scarcely turbid. To the west of the divide no jungles exist, the forces of insolation and deflation are at a maximum, and in the softer rocks the loss by degradation since Pliocene times is almost inconceivable.

The division of the plateau into isolated blocks by the incising action of the streams is associated in its first stages with impassable gorges. This arose from the early approximation of the cañons to base-level as head-water corrasion proceeded. Falls, among which may be cited the Apsley, Tia, and Wooloomumbi, originating on the three thousand three hundred feet level flow along channels, a few miles below their point of departure from the plateau, about two thousand five hundred feet lower than the plateau.

The lower portions of the stream had, however, by this time reached the mature stage of development. The Middle and Lower Hunter valleys, as also those of the

Macleay, Peel, and Gywdir, were from five to ten miles in breadth, and afforded numerous facilities for settlement, both by reason of their well-developed river flats and the means of communication between towns along their banks.

A remarkable adjustment of streams to structure accompanied the erosion of the plateau, a fact described more fully elsewhere. (*Ante*, pp. 166–170.)

After the forces of erosion had excavated deep valleys in the Sandon and Stannifer peneplains, another basaltic demonstration took place in New England and associated areas, but on a reduced scale to that belonging to the middle or late middle Tertiary Period. The streams of this recent period possessed large deposits of stanniferous drift, and these the basalts covered up and have preserved until the present day. Examples of these later leads are the various old alluvial tin deposits at Elsmore and Newstead.

Craters were developed during this late period of volcanicity. A considerable proportion of the later basalt in the Emmaville district belongs probably to this period*, although it must be remembered that the Emmaville and Nine-mile leads themselves lie on the Tertiary plains.

The history of volcanism and plutonic intrusions in New England and associated areas is one of great interest.

In the first place we have an extensive series of alternating basic (dolerites and basalts) and acid (rhyolites) lavas in Devonian time. Associated with these are basic sills. Strata containing numerous lepidodendra remains accompany the lava sheets.† The Devonian lavas thus appear to have been extruded over a subsiding area.

In the second place, the great mountain-making period of the Carboniferous was accompanied by the repeated intrusion of huge acid bosses into the areas of elevation. Associated with these plutonic masses are acid hypabyssal rocks. An examination of these rocks shows that an enormous period of time elapsed between the early and closing phases of this widespread intrusive activity.

Here, then, in an area of elevation, acidic intrusions are shown to have taken place on a magnificent scale.

In the latest Carboniferous Period, a great alternating series of dolerites and rhyolites was developed in an area of subsidence.

Coming to Triassic or Jurassic times, we have evidence of repeated basic lava extrusions in an area of subsidence alternating with minor oscillations of level.

Lastly, in Tertiary time, several distinct periods of intense volcanism occurred, the products being basic, and the area affected by the outbursts being one of elevation.

* T. W. E. David.—Geology of the Vegetable Creek Tin-mining Field. Memoirs Geol. Survey, N. S. Wales. Geology I, pp. 60–62.

† E. C. Andrews.—Report on the Yalwal Gold-field. Mineral Resources No. 9, pp. 14–17, 21–27.

Acid rocks form by far the greater portion of the Palæozoic igneous masses, if we include those of plutonic origin, while Mesozoic and Tertiary outbursts are almost entirely basic in nature.

The alternation of basic and acid flows is associated with areas of subsidence, while the plutonic acid intrusions and the greater portion of the basic flows occur in regions of elevation.

To these notes may be added the following:—

1. Of the earlier volcanic flows, those of acid nature are larger than the basic ones.
2. In regions south of New England, large acid porphyry flows* occurred in Devonian time unaccompanied by basic extrusions. Such are the Snowy River porphyries. In this southern region, mountain-making on a large scale had preceded the Carboniferous period.† Into the areas of great elevation, masses of Carboniferous or pre-Carboniferous granite and other acid plutonic rocks appear to have been thrust. Insignificant dykes and sills of syenite and basic andesites‡ are associated with the great acid bosses.
3. In New England, the older fine-grained granite is decidedly more acidic in character than the later and more extensively developed masses of sphene-hornblendic granitite.

From these observations, there appears to be reason to assign a deep-seated origin for the lavas and other igneous masses, also to postulate remarkable differentiations of a common magma from time to time, the acidic displays preceding the more basic ones.

The extensive series of Devonian, Carboniferous, and Permo-Carboniferous basalts and rhyolites over a sinking area could be explained by heavy weighting and consequent forcing aside of the major portion of the underlying igneous masses to regions of less pressure, a smaller residual portion under excessive stress of weighting forcing itself upward along lines of weakness in the soft recently-formed strata.

The great Tertiary basalt extrusions are also explicable on this principle. In this case, however, the material forced aside by the Cretaceous loading found the elevated crust a line of weakness.

The Carboniferous and later granites represent release of pressure in rising areas, the long-continued action of the Gympie and later foldings permitting of repeated intrusions of deep-seated rocks, the varying compositions of which, also, probably show a differentiation of some magma, the nature of which at present we have little or no knowledge of either as to its chemical composition or physical characters.

* A. W. Howitt.—Geol. Survey of Victoria. Progress Report for 1876-1877, pp. 181-244.
† T. W. E. David.—Presidential Address. Linn. Soc., N. S. Wales, 1893, pp. 563-584.
‡ E. C. Andrews.—Report on the Kiandra Gold-field. Mineral Resources, No. 10, pp. 13-14, 17-18

Similarly for the wonderful alternation of Palæozoic basic and acid lava flows.

To return from this digression we find that while yet the effects of river rejuvenescence had not been effaced, great waterfalls and cataracts still forming the upper courses of the rivers; and stream recession had not yet conquered the central portions of the plateau, except in the case of that important consequent stream, the Hunter, the coastal area was gradually depressed. The amount of sinking was not at all comparable with the movement involved in the great late Tertiary uplift, yet so pronounced were its effects as to profoundly modify the coastal topography. The coast which had been developed to maturity and old age during the cycle of erosion and deposition attendant on the Pliocene uplift was now lost to the land surface. Streams were betrunked; river valleys converted into arms of the sea; and side channels of the same converted along their lower courses into repeatedly ramifying fiords. The extensive shoals and bars resulting from the marine distribution of fluviatile material during a long period of subaerial denudation succeeding to the Pliocene uplift were submerged, the coast was foreshortened, and the hitherto harbourless coast-line became possessed of a series of magnificent shelters such as Botany Bay, Port Jackson, Hawkesbury River, Port Stephens, Myall Lakes, and the various river estuaries of the north coast. These harbours were much more open for navigation purposes then than at present; in the first place, because the rate of the sinking probably far exceeded that of subsequent infilling of the bays by sedimentatation; and, secondly, recent elevation has exposed shoals formerly well-covered with water.

In certain areas the movement appears to have been slow (Pl. XXXVI, fig. 2) and accompanied by concomitant sedimentation*, especially in the Great Barrier Reef locality, where traces only of cliffs occur associated with extensive masses of redistributed fluviatile material. The association of these forms with bay bars, probably, is the outcome of recent elevation.

From Sydney to the Manning River, the presence of considerable cliffs point to a period of quiescence during which the coast-line could be cut back. The association of these cliffs with coastal plains emphasises this point.

The influence of the subsidence is more noticeable in the southern portions of the area. The lower portions of the Hawkesbury furnish beautiful examples of drowning. Silting, however, has gone on to such an extent that the wide channel is navigable now with flat-bottomed boats only.

Port Jackson shows a betrunked stream, owing its commercial importance to the negligible current of the streamlets flowing into it, which, possessing insignificant volumes only, have been unable to silt up the waterway. The narrow entrance to the harbour also reduces silting up by alongshore action to a minimum. The deep

* E. C. Andrews.—Notes on the Geology of the Queensland Coast. Proc. Linn. Soc. N. S. Wales, 1902, p. 177.

water immediately off shore also allows of the dumping down of considerable quantities of *débris* before the filling-up process ensues. The innumerable coves ramifying from the main channel represent side valleys to the old stream.

Botany Bay furnishes another example of a drowned valley. Formerly George's and Cook's Rivers were united, and flowed out to sea through Botany Heads. After the formation of the valleys by subaerial erosion, subsidence supervened, shoals were formed which became converted during a later period of elevation to coastal plains, showing aggradation lines of low sand-dunes. Behind these comes a lagoon marsh-meadow.

Jervis Bay affords another magnificent instance of a harbour formed by drowning. The late age of the submergence is shown well by the little loss to the capes protecting these harbours by marine erosion, and the slight subsequent modification of the river valleys by subaerial denudation. Before the stage of maturity is reached for this coast-line, all the harbour headlands must be cut away, the harbours filled, and the coast-line form a series of swinging curves.

It is possible to arrive approximately at the amount of drowning which the coast-line has sustained. The rivers had developed base-level valleys for many miles in from the coast, and the depression allowed the sea to trespass only so far along the river beds that the parts which approximated closely to sea-level only were inundated. At any rate, that was the state of affairs for the coast associated with the New England plateau. Along the northern coast of Queensland the drowning appears to have been more pronounced. In the opinion of the writer, a subsidence of several hundred feet is more than sufficient to explain the drowned shore-line topography, although the movement was doubtless differential in an east and west direction, and accentuated easterly.

Although the great cycles of Tertiary elevation for New England and the associated regions were probably determined by secular movements, yet the loading of the offshore areas resulting from the enormous degradation of the land surface raised in late Tertiary time may have been a sufficient cause for the Pleistocene or late Pleistocene drowning of the coastal area.

The attack on the plateau still progressed, the waterfalls and mountain tracks being as busy as ever furnishing in flood-time *débris* for aggradation purposes lower down stream. Gradually the estuaries and bays, with associated rivers which had formed magnificent harbours during the early stages of the cycle of subsidence, became partially silted up, while surplus material carried out to sea was redistributed by marine agencies to form extensive shoals.

Nips first (Pl. XXXVI, fig. 2), and subsequently cliffs, were imposed upon the wooded spurs which had dipped into the sea as a result of drowning, and the material furnished by their formation helped to swell the magnitude of the offshore deposits.

The intention of the sea to establish a straight or gently swinging coast-line now became plainly evident. The rivers were incapable of building up deltas, along-shore currents destroying the fluviatile deposits as soon as formed. A dominant current from the south swept the material lost to the islands and mainland by subaerial and marine agencies round the isolated hills near the river mouths, and so gradually altered the normal direction of the streams until now in the north-east of the State they pursue final courses, having northerly directions.*

Although these shoals are the expression of work effected since the cycle of drowning was inaugurated, yet it is a mere fragment of what has been accomplished since the great Pliocene uplift. The rivers had practically reached the same stage of development at the commencement of the drowning process which they possess at present. They had carried on the process of rock selection, inaugurated in a previous cycle of erosion, until channels along the softer rock exposures had been developed many miles in width mainly by the forces of lateral corrasion. And all this had been the work of denudation before the recent subsidence. This may be seen by an examination of the watercourses along their drowned and unsubmerged portions. A study of the harbours also assists in arriving at this conclusion. The harbours are only partially filled, and the headlands are in much the same condition as that obtaining prior to their drowning. It must also be borne in mind that the cycle of erosion attendant on the Pliocene uplift was accompanied by deposition which would produce extensive smooth offshore deposits. In fact, the amount of such sedimentation may be approximately ascertained, it being determined by the removal of the material in excavating the Macleay, Clarence, and other valleys out of the plateau. Thus no great hollows were left for the late Pleistocene deposits to fill up, the function of such recent sedimentation being to silt up the present harbours and form coastal plains on a smooth Pliocene base.

A study of the coast from Sydney to Cooktown, however, reveals variations from north to south in the extent of drowning and in the time involved since such movement, all, however, taking place in very recent geological times. The varying coastal forms may be, however, partly explained by differential obduracy of resistance of the rocks to the forces of erosion.

A vibratory movement of elevation in recent times converted these recent offshore deposits into coastal plains, which become very pronounced north of the area immediately under discussion. Raised beaches recur along the Hunter River,† Richmond River,‡ and Evans River.§ Criteria of elevation have also been observed by the writer at Tweed Heads, Byron Bay, Clarence River, Nambucca River, Macleay River, Raymond Terrace, Lake Macquarie, Woy Woy (Hawkesbury River), Botany Bay, Dapto, Albion Park, and other places.

* Portions of the Clarence River, as also the Orara, are subsequent streams.
† David and Etheridge.—Rec. Geol. Survey, N. S. Wales, 1890, ii, Pt. 2, pp. 37-52, Pl. 3
‡ J. E. Carne.—Ann. Rept. Dept. for Mines N. S. Wales, 1896, p. 151.
§ G. A. Stonier.—Ann. Rept. Dept. for Mines N. S. Wales, pp. 129-130.

The evidence yielded by a cursory examination of these localities consists for the most part in the occurrence of extensive flats from five to ten feet above sea-level, situated so that in many cases floods cannot reach them, and existing in such quiet spots that waves could not have been instrumental in heaping them up. Another feature of these deposits is that they frequently contain vast quantities of marine shells. These flats may be studied well along Lake Macquarie shores and the quiet reaches of the Lower Hawkesbury River. The Brisbane express passes over one such sandy plain crowded with shells at Woy Woy, near Gosford. In other localities aggradation lines are formed by the sand dunes composing the extensive flats. These lines, curving sympathetically with the coast, suggest marine action at a lower level, the present high and dry position of the plains being due to elevation.

The effects of the recent elevation are more marked in the northern than in the southern areas. Beautiful examples of swinging coastlines, lagoons, lagoon-marsh meadows, coastal plains, island tying, bay bars, and greatly deflected streams occur immediately north of the Tweed River, and in a minor degree around the lower portions of the Tweed, Richmond, Clarence, and Macleay Rivers. From these facts we can easily arrive at a knowledge of the stage of development attained by the coast, although it must be borne in mind that the main facts of form as regards the coastline were really determined by an epoch of erosion succeeding to that of uplift, and modified by Pleistocene drowning and marine erosion, the present features, such as shoaling, being merely accentuations of the former activities by a slight movement of elevation.

Barrier Reef problems are possibly best attacked from a study of the associated coastal and plateau topography. The coastal area associated with the New England plateau is in extra-tropical regions, but an examination of the North Queensland coast district reveals much that is common with the region dealt with in the present discussion. Between Townsville and Cooktown the remnants of a high plateau advance great spurs into the sea. Many islands, thousands of feet in height, rise from the shallow water of the continental shelf, separated from each other and the mainland by long water-lanes. By following the interinsular salt water channels and the mainland they are found to be continuous with old subaerial watercourses, which in turn are observed a few miles inland to descend the plateau in a series of gigantic waterfalls. Among these may be mentioned the Tully, Barron, and Johnson Falls. Above the falls the rivers run in broad valleys, surrounded by very high mountains, flat-topped in places, and four thousand to five thousand feet above sea-level. Here, then, a couple of peneplains, probably of Tertiary age, have evidently been raised to form two plateaus of erosion. A cycle of denudation, dating possibly from Pliocene times, allowed of the formation of deep and broad cañons in the uplands since the last considerable uplift. Islands

like Hinchinbrook, South Palm, Gloucester, Fitzroy, Capes Cleveland, Melville, and Grafton represent isolated portions of these Tertiary plateaus, by forces of erosion acting during and subsequently to Pliocene times. The rivers along their lower courses were not far removed from the base level of erosion, especially in the region of the present Barrier Reef. Long-continued sedimentation also acted in the same region during this grading process to form an extensive series of sandstones, mudstones, and calcareous strata, resembling the Pliocene "Fiji soapstones," and limestones underlying the widespread recent raised coral reefs of Fiji.

After the formation of the wide valleys during late Pliocene and Pleistocene times a differential subsidence took place for the coastal area. The coastal plains were drowned, rivers were betrunked, and those portions of their side valleys which had been cut down to a point near sea-level were converted into arms of the sea. For fuller information concerning the topography of North Queensland coast see a paper by the Author "Notes on Queensland Coast Geology"—Proc. Linn. Soc. N. S. Wales, 1902, pp. 146–185.

The formation of the present Great Barrier Reef probably does not ante-date this last movement of subsidence, although reefs doubtless existed prior to the cycle of subsidence. Unless the movements of subsidence were accentuated in an easterly direction, the depression which determined the Barrier Reef must have been very moderate in amount. Were a bore put down in the Great Barrier Reef, it would probably show a very moderate thickness only of bedded recent or at most Pleistocene coral lying on mudstones, conglomerates and limestones of Pliocene age. The basal Pliocene beds will doubtless be well stratified as is the case in Fiji. The Barrier Reef, as also the recent raised reefs of Fiji,* Tonga, and other island groups are unstratified and quite distinct from the underlying limestones, conglomerates, &c. Extensive shoals were formed either during or subsequent to the cycle of coastal subsidence. Portions of these became dry land by the action of the next coastal elevation.

Significance of Topographical Features.

Had New England not participated in the great Pliocene uplift, it would have presented the aspect now of magnificent plains reaching from the coast, and separated only from those to the west by an insignificant divide generally less than three hundred feet in height. Through the low gaps the coastal rains could reach the western district. Over these plains sluggish rivers would hold their way. The highest mountains would be flat-topped or conical generally basalt-capped, and not exceeding two thousand feet in height. Enormous quantities of gold and gems would occur in the deep river drifts, and the pebbles in the stream beds would be intensely waterworn.

* E. C. Andrews.—"Notes on the Limestones and general Geology of the Fiji Islands," Bull. Mus. Comp. Zoology Harvard, 1899. xxxviii, pp. 31–34.

The rainfall would be more abundant on the west and less pronounced on the eastern falls than at present, and the fertile plains of the west would doubtless possess many characters in common as regards vegetation with the dense "brushes" of the coast. Thus the settlement of millions of people would have been assured.

There would, however, have been no harbours of note, enormous sandbars, gently sloping cuspate-forelands, and extensive "shallows" would have hindered navigation. The coast would have presented the appearance of a monotonous plain with straight and gently curved shore lines, with rivers bar-bound and deflected northwards near their mouths.

The influence of the uplift was to render the extensive plains of late Tertiary age unfit for habitation, except in the initial stages of erosion. As, however, the plateau was trenched by the corrading waters, so the formerly smooth surface became gradually more unfitted for settlement. At present a whole strip of land comprising the country for twenty or thirty miles east of the plateau is unoccupied except by a few cattle and sheep owners. This inhospitable tract of New England will never be fit for purposes of close settlement. A similar state of affairs exists in the dissected country west of the plateau.

The effect of the late subsidence was to form a series of harbours along the coast and to give birth to the Great Barrier Reef, while that of recent elevation was to undo much of the good brought about by subsidence.

Summary of History.

1. Devonian sedimentation.
2. Probable folding which checked Devonian sedimentation, and ushered in the Carboniferous (Gympie).
3. Great mountain-making period, long-continued folding, and repeated granite intrusions of Carboniferous sediments.
4. Long-continued denudation.
5. Deposition of Upper Carboniferous.
6. Deformation and degradation.
7. Deposition of Permo-Carboniferous (Coal seams, ice ages), closing phases of granitic intrusions.
8. Early Mesozoic earth movements.
9. Triassic and Jurassic sedimentation, accompanied by basic lava flows and coal seams.
10. Deformation ushering in Cretaceous period.
11. Cretaceous sedimentation. Development of Bolivia and Mole peneplains by subærial denudation, the two activities being separated by an uplift of five hundred feet.
12. Tertiary elevation of New England (one thousand feet). Pronounced sedimentation.

13. Partial reduction of Cretaceous plateaus, great middle Tertiary basalt demonstration, and formation of Sandon and Stannifer peneplains, by cycle of subærial erosion.
14. Pliocene (?) uplift of New England. Vertical movement, three thousand three hundred feet.
15. Partial reduction of plateau. Adjustment of stream to structures. Development of large flood plains.
16. Recent subsidence of coastal area. Formation of harbours and Great Barrier Reef.
17. Silting up of harbours and Pleistocene sedimentation.
18. Slight movement of elevation in historical period. Formation of coastal plains, and shoaling of harbours.*

APPENDIX.

Possibly the best localities for studying the Mole Plain are to be found east and south-east of the Mole Table-land itself. These points would include the country between Tenterfield, Stanthorpe, and Wilson's Downfall, that also east of Bolivia, and the country between Glen Innes, Oban, and Guy Fawkes. In these localities the Mole Plain remnants may be described as unakas or mountain masses, being, in fact, even more important features in the topography of the northern plateau proper than the ramifications of the Stannifer Plain itself. Of course this must be understood for the central elevation only, as the residuals of the Mole Peneplain to the east have suffered almost complete reduction. From Mount Spiriby, a monadnock of the Cretaceous and probably a survival from Jurassic denudation the relation of the Stannifer, Mole, Bolivia, and higher plains (existing simply as several isolated cones) can be best studied. Spiriby itself is a cone 5,000 feet high, and composed of spherulitic rhyolites. Deformation or oscillations of level are seen to have occurred about the time of the late Tertiary uplift, as evidenced by the aggradation plains of the central plateau (Stannifer Plain) at Glen Innes.

The Hunter exemplifies the development of a contour stream at the expense of other consequent rivers. Originally insignificant, it captured the Williams and Paterson streams after they had enlarged themselves by subsequent courses; and then developing a subsequen' course to the north, it tapped various tributaries of the Namoi.

The Manning River is now in turn enlarging itself at the expense of the Hunter, as may be seen at the Oakey and Horham Creek Gap in the Tomalla Tops.

Possibly one of the finest studies in New South Wales of river and plain development is that afforded by an examination of the Hawkesbury basin. Signs of four distinct cycles of denudation are shown for the area in question, as is the case also in New England. The fuller account of its history is reserved for a future paper, but briefly it appears to have been as follows:—

At the close of the Trias-Jura, the Hawkesbury sandstone and underlying layers experienced a differential elevation accentuated in a westerly direction. The greatest elevation probably did not exceed 1,000 feet, and this was in the Devonian and Silurian strata in the neighbourhood of Bathurst, and against which the Trias-Jura series rested.† A long period of Cretaceous denudation ensued, resulting in the almost complete planation of the elevated Devonian and Silurian strata and of the upper elevated layers of the Hawkesbury sandstone on its western edge. The most important geographical fact of this age however was the gain to the dry land of a long, gently-sloping upland. This pronounced cycle of denudation and degradation, using these terms in sense of vigorous and slowly-acting erosive activities† respectively resulted in the formation of a plain of which Sunny Corner, Mount Binda, the Stony Ridges, Mounts Lambie and Walker, and Mount Clarence are at present residuals.

* Prof. W. M. Davis.

† Physiographic evidence points to the uppermost of these series as being Jurassic.

This marks the 4,200 foot level, and may be correlated with the Mole Peneplain of New England. It must be remembered that these elevations were in the form of a central, wide, horizontal plateau, with downfolded eastern and western limbs.

The planation was so perfect that insignificant residuals only remain above the Mole level. Examples of such "inheritances" handed on to the Tertiary cycle are the Sunny Corner Mountain and the summits of Mounts Lambie and Walker, the whole slope at the close of the cycle from the sea to Bathurst appearing as a monotonous plain, the even sky-line being broken here and there only by gentle hills.

After this most pronounced planing-down in Cretaceous time, another and more decided elevation occurred, attaining a maximum of about 1,000 feet in the neighbourhood of Sunny Corner and Rydal. The elevation was still tolerably horizontal at the centre, with flexed eastern and western limbs. The development of another plain was commenced and continued during the greater portion of Tertiary time. The result of these activities was the formation of another wide peneplain, which may perhaps be called the Lithgow Plain. This peneplain may be correlated with the Stannifer and Sandon plains of New England. Orange, Blayney, Oberon, Hill End, Wattle Flat, Rydal, Bowenfels, Lithgow, Lawson, Springwood, and Hornsby are points on this peneplain. The upland between Hornsby and the Hawkesbury is a beautiful example of this level. East and west may be seen the slight residuals of the Mole Plain. From Sydney one may see the large western residuals of the Mole, known as Mount Tomah and Mount King George rising above the gently-sloping upland of the Blue Mountains. Mount Victoria, Blackheath, and Mount Clarence mark other residuals overtopping the Lithgow or Blue Mountain Plain at Lithgow, Wallerawang, and Rydal. Still larger residuals occur near Rydal and Bathurst, as Mount Lambie and the Stony Ridges (Devonian quartzites.) Large sluggish rivers wandered over the broad Tertiary valleys (plains), whose floors were raised but little above sea-level.

The western residuals of the Mole Plain rising above the Lithgow Plain are naturally much higher and broader than those to the east, since elevation was accentuated westerly and erosion easterly, the rivers having larger volumes nearer their mouths, plains being developed easterly along the river-courses before the western upland was at all influenced by headwater corrosion

When the broader features of this peneplain had been developed, a great basaltic outburst occurred, burying the wide river-beds and their deposits of well-rounded wash.

The cycle of denudation had not been completed at the time of the volcanism. The existence of basalt covered leads at slight elevations above the peneplain shows that the cycle of development still continued for a considerable period, since erosive activities are slowly acting when denudation is giving place to degradation.

In late-Tertiary times, although possibly prior to the Pliocene period, came the grand uplift which transformed the low-lying Lithgow peneplain to a plateau 3,100 feet above sea-level, as at Rydal, Lithgow, Oberon, Hill End, and Wattle Flat. Orange and Blayney show the influence of western flexing. Warping also occurred as explained in the main report, especially marked in the areas north-west and south of Sydney. One of the results of this was to cause the (?) Pliocene Hawkesbury in the neighbourhood of Glenbrook to leave the old plain it had developed for itself in Tertiary times and occupy a lower place by sawing across the anticline opposed to it.*

The succeeding Hawkesbury history is a long story of river piracy and cañon formation, as explained earlier in the report. Probably the Nepean was originally a consequent stream prior to the development of the long subsequent course of the Hawkesbury. This capture converted the Nepean into an obsequent stream. A second period of volcanic activity probably occurred since the late-Tertiary uplift, as shown by the Bald Hills of Bathurst, where buried river-gravel overlain by basalt occupies a position lower than the Lithgow level and higher than the present Macquarie Plain.

The influence of the soft Wianamatta shales is evident in the development of the Hawkesbury at Penrith.

* For fuller information concerning this folding and faulting, see—(*a*) Proc. Roy. Soc. N.S.W., 1896, pp. 32–70, by Prof. T. W. E. David. (*b*) On the occurrence of an important geological fault at Kurrajong, P.L.S. N.S.W., 1902, Prof. T. W. E. David.

XX.—Mineralogical Notes, No. 8: by GEORGE W. CARD, A.R.S.M., F.G.S., Curator and Mineralogist.

[Plates XLII–XLIV.]

NOTE.—The asterisk prefixed in certain cases denotes that no reasonable doubt can exist as to the accuracy of the locality quoted.

**Bismuthinite.*—Duckmaloi Creek, Oberon District. Associated with copper-pyrites, cosalite, and quartz, in a matrix of garnet, epidote, and calcite.—Bow Creek, Deepwater. Occurs massive in a gangue of quartz and felspathic material, together with a little copper pyrites.

**Bismuth Carbonate.*—Duckmaloi Creek; as above.

Bismuth Ore.—Thirty miles west of Armidale. Mispickel in granite, assaying about ·5 per cent. of bismuth.

Cerussite.—Cangaira, Parish Taunton, County King. A massive variety, assaying 3 dwts. of fine gold and 509 ozs. of fine silver per ton of ore.

**Cinnabar.*—Five miles south-east of Pretty Gully, Drake District. Little crystals in pyritous saccharoidal bluish quartz. The crystals are splashed through the quartz, and are also sometimes located at the junction of the bluish and pinkish portions of the quartz.

Cobalt Ore.—Maybell, north of Broken Hill. Cobaltiferous mispickel, with a gangue of quartz and felspathic material. Assays of nearly 2 per cent. of metallic cobalt have been obtained.

The E.C.B. Mine, Burraga. A sooty mixed sulphide ore, containing gold, silver, lead, copper, and about ½ per cent. each of metallic cobalt and nickel.

**Copper Pyrites.*—Duckmaloi Creek, Oberon District. A massive peacock variety, associated with bismuth ores in a matrix of garnet with epidote and calcite.

Fluorite.—Nymagee. An amorphous purple variety in quartz.

Gold with Wolfram.—Fifty miles west of Wyalong. The ore consists of white quartz, with wolfram, and assays 28 dwts. fine gold per ton.

**Galeno-bismutite.*—Kingsgate Bismuth Mine. The mineral is somewhat fibrous in structure. Specific gravity, 6·782. An analysis has been made by Mr. H. P. White, Assistant Analyst to the Department of Mines. Metallic bismuth and lead with sulphate of lead and sulphur make up nearly 99 per cent. of the mineral; the balance comprising, in addition to gangue, antimony, copper, and a little silver. Neglecting the oxygen in the sulphate, and calculating to one hundred, we have

Bismuth, 58 per cent.,
Lead, 27 ,,
Sulphur, 15 ,,

which is very near the theoretical formula of galeno-bismutite, viz., Pb. Bi_2S_4.

**Meteorites—*

(1) The Mount Browne Meteorite. (Pl. XLII.) An Aerolite. This meteorite fell at Mount Browne, New South Wales, at about 9·30 a.m. on 17th July, 1902. Just before the fall an explosion had been heard, immediately after which a hut caught fire. A whizzing sound followed, and the meteorite struck the ground some distance away from the hut, raising a cloud of dust. It was picked up by W. Jordan a few minutes after its fall, and while still warm.

A black skin of fused material envelops the meteorite, and the usual 'thumb-marks' are visible. A portion from one end was broken away by the finders. The interior is fine-grained, and light-grey in colour—probably exceptionally so for a meteorite. It is stony in texture, and shows numerous little glancing faces of metallic iron of a pale, brassy appearance. An analysis is now being made by Mr. Harold P. White, Assistant Analyst.

The present weight is 25¼ lb., and it is believed that at least one pound was broken off by the finders.

(2) The Mount Dyrring Meteorite. (Pl. XLIII.) An Aerolite. This is represented now by some masses of oxidised material just discovered by an aboriginal at Mount Dyrring, eight miles north of Bridgman, in the Singleton District, New South Wales. The material was embedded in the soil. Under the supposition that it was an ore of some metal, the finder had several assays made; and eventually a specimen was sent to the Geological Survey Offices. Soon after, Mr. E. C. Andrews, Geological Surveyor, visited the spot and secured what was left, other than very small pieces. The mass is readily broken, so that the largest piece now intact weighs 4½ lb. The total quantity acquired was 25 lb.

The meteorite consists of kernels of fresh, pale-green, vitreous olivine, of the size of a large Spanish nut, enveloped by a skin of metallic iron in an advanced state of rust. The pseudo-crystalline appearance of the olivine kernels gives a macro-chondritic aspect to the whole mass. The meteorite is evidently closely related to the Pallasite group. Mr. J. C. H. Mingaye, Analyst to the Geological Survey, is making an analysis of the stony portion.

The Mount Browne and Mount Dyrring meteorites have been acquired for the Mining and Geological Museum, Sydney.

(3) Obsidianite. Bull and Damper Creek, Quartzville, Tumbarumba, New South Wales. (Pl. XLIV, fig. 1.)

This was found in an alluvial working. A perfect specimen.

(4) Obsidianite. Liverpool, New South Wales. (Pl. XLIV, fig. 3.)

Found in ploughing a field. A perfect specimen.

(5) Obsidianite. Bimbowrie, South Australia. This specimen is the property of the finder, Mr. G. R. Howden, of Mount Howden, Bimbowrie. The specimen was much worn. It is of the usual bi-convex type, with a medial fluted region occupying about one-third the total thickness, and bordered on one side by a ridge.

(6) Obsidianite. Bell's Creek, Braidwood, New South Wales. A perfect specimen, found in alluvial. (Pl. XLIV, fig. 2.)

**Molybdenite.*—Bow Creek, Deepwater. Pretty rosette-like laminated crystals, up to about two inches in diameter, in a matrix of white quartz.

Also near Deepwater, molybdenite is found in massive felspar.

At Whipstick it is associated with garnet in granitic rocks.

At the Federal Mine, Kingsgate.

Opal.—Milk opal. Thirty-five miles from Nyngan, between Mudal and Nymagee.

Wolfram.—Duckmaloi Creek, Oberon District. Pieces of considerable size in quartz.

XXI.—Notes from the Chemical Laboratory, Department of Mines: by JOHN C. H. MINGAYE, F.I.C., F.C.S. Analyst and Assayer.

No. 1.

On the Occurrence of Vanadium in various Minerals, Rocks, Coals, Bog-head Minerals, Clays, &c., in New South Wales.

THE presence of very small amounts of Vanadium has been recorded in various rocks, iron, ores, bauxites, coals, bog-head mineral, clays, &c. In thirteen samples of basalt which were submitted to a complete analysis the amount determined varied from a trace up to ·06 per cent. off V_2O_5.

Several iron ores received for examination were coated with patches of a greenish-yellow colour, which readily gave a strong reaction for Vanadium, and in several samples of bauxite examined traces were found to be present.

In a sample of coal from the Leconfield Colliery, near Branxton, New South Wales, Vanadium compounds were readily visible, occurring in the clay bands through the coal, which were stained a yellowish-green colour. Vanadium was readily detected in the colouring matter.

A large number of ashes from coals have been examined on various occasions, and in nearly every case were they found to contain traces of V_2O_5. The following are some of the estimations made :—

Percentage V_2O_5 in the Coal.

Assay Nos., 1899.	3054.	3055.	3059.	3560.	3561.
V_2O_5 :—	0·02 %	0·03 %	0·03 %	0·04 %	0·12 %

The ashes of the New South Wales bog-head mineral, or so-called "Kerosene Shale," more or less, contains traces of Vanadium. Ten samples of the ash under examination yielded traces of V_2O_5 (less than 0·01 per cent.). The following estimations were made :—

Percentage of V_2O_5 in the Mineral.

Assay Nos.	3725.	3724.	3730.	3731.
V_2O_5 :—	0·01 %	0·02 %	0·05 %	0·01 %

The clays and shales in the County of Cumberland, as a rule, contain small decimal quantities of Vanadium. On being manufactured into bricks, and standing exposed to the weather, the bricks show on the surface a yellow-greenish and reddish stain, which stands out in relief from the colour of the bricks in patches, spoiling to some extent the appearance of the buildings. The colour has been observed in red bricks, but is more noticeable where light-coloured bricks have been used.

The colouring matter is soluble in water, giving a strong yellow solution, and consisting largely of vanadate of potassium.

In Muspratt's "Chemie in Anwendung auf Künste und Gewerbe" it is stated: Clays, after burning at a temperature below that of melting silver, and after long standing in the air, show yellow, grass-green, or bluish-green surfaces, caused by compounds of Vanadium. If containing water, green or blue, anhydrous-brown.

An analysis is also given of a solution obtained by soaking portions of the stained bricks in distilled water for some days, the extract being of a yellow colour.

In 100 parts (Muspratt's "Chemie").

Vanadiate of Potassium	44·38
Molybdate ,,	1·62
Potassium Sulphate	9·01
Calcium Sulphate	7·97
Magnesia	10·02
Sodium Chloride	4·47
Silica (soluble)	3·82
Water	18·25
Insoluble Matter	·46
	100·00

Professor E. A. Rennie, in 1883, read a paper before the Royal Society of New South Wales "On the discolouration of white bricks made from certain clays in the neighbourhood of Sydney," and was the first to note the presence of Vanadium in the white bricks manufactured from the clays in the County of Cumberland.

A white clay obtained from Newbridge, County of Bathurst, yielded on analysis, 0·08 per cent. of V_2O_5 the largest amount hitherto found in any of the clays examined in the Laboratory.

The percentage of V_2O_5 is usually very small—from traces up to 0·02 per cent.

The presence of Vanadium in lignite, peat, sandstone, clays, rocks, slag, &c., has been pointed out by various authorities. An analysis of the ashes of a Vanadiferous lignite in the Argentine Republic yielded 38·22 per cent. of V_2O_5. The ash was green in colour, the coal containing 0·63 per cent. of ash.

No. 2.

On the Occurrence of Vanadium in the ashes of Scotch Oil-bearing Shales.

Having occasion to examine some twenty samples of Scotch shales for Mr. J. E. Carne, Geological Surveyor, the ashes of twelve lots were tested for the presence, or otherwise, of Vanadium, and in every case was it detected. The following estimations were made :—

Percentage of V_2O_5 in the Shales.

Assay Nos.	**133.**	**134.**	**135.**	**136.**	**137.**	**138.**	**139.**	**140.**	**141.**	**142.**	**143.**	**144.**
V_2O_5 :—	0·01%	·02%	·04%	·02%	·01%	·02%	·04%	·08%	·12%	·08%	·07%	·06%

The ashes of these shales consist mainly of silicate of alumina. A trace of Cr_2O_3 detected in three of the samples.

No. 3.

Montanite from Nanima Bismuth Mine, near Yass, New South Wales.

Mineral, massive; colour, brown. Partially soluble in dilute hydrochloric acid. Specific gravity, 6·823.

Chemical Composition.

Bismuth...	57·73
Tellurium	19·15
Selenium	trace.
Iron	·40
Copper	·24
Manganese	1·78
Lime (CaO)	trace.
Magnesia (MgO)	·08
Insoluble Matter	2·52
Carbon Dioxide	1·05
Water	1·61
Oxygen (by diff.)	15·44
	100·00

The absence of gold, silver, sulphur, and sulphur trioxide proved.

The manganese is present as MnO_2. A few small specks of a steel-grey foliated mineral were observed in the various pieces sent for analysis, which were found to be Tetradymite. The mineral is evidently an alterative product of the Tedradymite, and a variety of Montanite.

XXII.—Notes on the Occurrence of Monazite in the Beach Sands of the Richmond River, New South Wales: by JOHN C. H. MINGAYE, F.I.C., F.C.S., Analyst and Assayer.

THE presence of gold, platinum, osmiridium, and tin in the beach sands of the Richmond River have been pointed out by the Author*, and these sands are extensively worked for the metals contained in them.

The sand consists largely of coarse white sand, zircons, quartz, ilmenite, and a small amount of cassiterite, platinum, iridosmine, and gold. To the above constituents present must be added monazite, which has been recently detected in the sands, and highly concentrated material.

A sample from Ballina, apparently somewhat concentrated, and consisting largely of zircons, was found to contain 14·92 per cent. of metallic tin; phosphoric acid, 0·447 per cent.; and 1·53 per cent. of the rare earths in the Cerium Group (*i.e.*, Ce_2O_3 La_2O_3, Di_2O_3, and ThO_2).

A sample of highly-concentrated sand from Broken Head, Ballina, Richmond River, furnished by Mr. H. R. Hammond for examination, was found to consist largely of monazite. The following is the analysis of the concentrates:—

Chemical Composition.

	I.		II.		III.		IV.
P_2O_5	18·89	.....	18·94				
Ce_2O_3	22·42	.....	22·72				
La_2O_3 / Di_2O_3	22·95	.....	22·78	.....	45·92	.....	45·99
Y_2O_3	·16	.....	not detd.				
ThO_2	·46	.....	·57				
SiO_2	6·68	.....	6·48				
Al_2O_3	·14	.....	·19				
Fe_2O_3	2·08	.....	1·96				
MnO	trace	.....	trace				
CaO	1·32	.....	1·40				
MgO	trace	.....	trace				
ZrO_2	15·36	.....	15·44				
†SnO_2	9·03	.....	9·12				
Ta_2O_5	1·10	.....	·86				
TiO_2	absent	.....	absent				
H_2O	·10	.....	·12				
	100·69		100·58				

Fine Gold.—A trace (under 1 dwt. per ton).

Platimum.—A trace (a few grains per ton).

Osmiridium " " "

NOTE.—The gold had been removed by passing the concentrates over amalgamated copper plates.

Sp. Gravity of Sand.—5·224.

* Journ[l] R. Soc. N.S Wales for 1892, p. 268.
† Metallic tin, 7·11%.

A previous sample from the same source ($\frac{1201}{02}$) yielded 14·99 per cent. of phosphoric acid. Sp. gravity, 5·088.

Mr. H. R. Hammond, Byron Bay, in a letter dated 9/8/02, states as follows, respecting the samples sent for examination :—"The samples forwarded are taken from the beach black sands, locality Broken Head, Ballina Mining Division. The black sand is first concentrated over tapestry carpets up to a certain grade. It is then re-concentrated in a wide box, following the law of gravitation to grade the tin ore up to a marketable standard of about 74 per cent. The residues are then run through a second time to extract further tin ore, the bulk being a heavy yellow sand, which I find impossible to separate from the ore. The second concentration I treat with a strong solution of cyanide for fifteen minutes, and then pass over copper plates to extract the gold and small quantity of platinum."

The gold being in a very fine state of division, and readily amenable to cyanide, I fail to see the use of treatment with cyanide, as a portion of the gold would dissolve, and not be recovered. The platinum and platinoid metals, no doubt, are recovered in the riffles.

Considerable deposits of monazite occur in the beach sands and placer mines in various parts of the world.* In Brazil deposits are found in the beach sands along the sea-shore, also in the gold and diamond placers of the Provinces of Bahia, Rio de Janeiro, and São Paulo; in the river-sands of Buenos Ayres, Argentine Republic, and the United States of Colombia; also in the placer gold-mines of Siberia, and in Southern Norway. Monazite has been recorded in New South Wales from Vegetable Creek, County Gough, †Tooloom alluvial gold-fields‡, in which it occurs associately largely with zircons, and the Richmond River district, and in Victoria at Bairnsdale. The economic value of monazite lies principally in the thoria contents, this being in the manufacture of the mantles for the Welsbach incandescent gas-light.

"The incandescent gas-mantles of commerce in use at the present time, according to Ernest Hintz, consist almost invariably of thoria and ceria (0·45—2 per cent.), with traces of lime, magnesia, and frequently small quantities of neodymia, yttria, and zirconia. The greatest power of emitting light is exhibited by a mixture of ninety-nine parts of thoria and one part of ceria, the emissive power of their mixture being fully ten times as great as that of thoria alone. The substitution of any other of the rare earths for the ceria tends rather to diminish than to increase the emissive power of thoria. The same is the case with lime (0·5%), which, moreover, renders mantles very fragile."§

The mantles are made from net-work woven out of strong cotton thread. They are then washed with an alkaline wash, preferably ammonia, and afterwards with

* Ann. Rept. U S. Geol. Survey, Part IV, 1891, p. 698.
† Liversidge, Minerals of New South Wales; p. 114.
‡ Austr. Assoc. Adv. Sci., 1898, viii. p. 333.
§ Zeit. Anal. Chem., 1898, 37, 94–111.

warm water, and carefully dried. After being cut into proper lengths and shaped, they are soaked in a solution of nitrate of thoria, and dried. On the ignition of the cotton fibre in the flame, a net-work of the oxides of the rare earths are left.

The method of analysis employed was that of Prof. S. L. Penfield,* with slight modifications :—

(A.) Two one grammes of the sand ground to an impalpable powder were placed in a small flask, and decomposed with ten cc. of H_2SO_4 (1 : 1), and warmed on the sand-bath for some hours (two to three), until nearly all the acid had fumed off, again treated with 5 cc. of acid, and the excess of acid removed by heat. About 25 cc. of cold iced distilled water was then added, and the solution filtered off from the insoluble silicates, tin oxide, &c. To the clear filtrate, largely diluted with cold water, an excess of oxalic acid was added, and the solution boiled for a few minutes, and allowed to settle in the cold for twelve hours.

The precipitate of the oxalates of the Cerium Group, including thoria, were filtered on to an ashless paper, well washed, dried, burnt at a low red heat, and weighed. Yielded as follows :—

	I.	II.
Oxides of the Cerium Group—	45·96%.	45·84%.

(B.) Two one grammes of the finely-powdered sand were fused in six grammes of fusion mixture, the melt leached with water, filtered, and well washed. The P_2O_5 in the filtrates were determined by neutralising the alkaline filtrate with HNO_3, and evaporating to dryness. Treated with a few drops of HNO_3, and filtered off from a small amount of tin oxide, and the P_2O_5 estimated in the filtrate by the Molybdate method. Yielded :—

	I.	II.		I.	II.
$Mg_2P_2O_7$—	29·54%.	29·62%	equal to P_2O_5—	18·89%.	18·94%.

The insoluble residue containing the Cerium Group—zirconia, cassiterite, ferric oxide, calcium carbonate, &c.—was incinderated, to this was added the small amount of tin oxide soluble in the alkaline fusion, the residue being placed in a porcelain boat, enclosed in a glass combustion tube, which was heated to a red heat for two hours, a continuous stream of hydrogen being passed through. On cooling in a current of hydrogen, the boat with contents was placed in a small beaker, covered with a watch-glass, and the reduced tin and iron dissolved out with dilute HCl, filtered off from the insoluble residue, and the Sn precipitated as sulphide by passing a current of H_2S through the solution. Yielded :—

	I.		II.
SnO_2	9·03%.	SnO_2	9·12%.

(1) The residue insoluble in HCl was ignited, placed in a small flask, and treated with ten c.c.'s of H_2SO_4 (1:1). (2) The filtrate from the precipitation of the sulphide

* Am. Journ. Sci. 1882, xxiv (3), page 253.

of tin was evaporated down to dryness, taken up with dilute H_2SO_4, and added to the above (1). This was found necessary as dilute HCl dissolved some of the earths. To the clear solution oxalic acid in excess was added, the precipitation being conducted as in A.

	I.	II.
Oxides of the Cerium Group found—	45·92%	45·85%.

Two of these precipitates were taken for the estimation of the thoria by the method given in Penfield's paper. By dissolving the mixed oxides in H_2SO_4, getting rid of the excess of acid, and working in nearly a neutral solution, dissolving in ice-cold water, adding $Na_2S_2O_3$ in excess, and warming for some time. The precipitated thoria collected on the filter, washed, ignited, and weighed. Found—

	I.	II.
ThO_2	0·46%	0·57%

The Ce_2O_3, La_2O_3, and Di_2O_3 were determined as follows:—

To the filtrate from the thoria precipitate was added an excess of NH_4HO_1, which gave a copious precipitate of the hydrates of the earth. This was allowed to settle, and then filtered off, washed, and dissolved in about five c.c. of HCl, and warmed until solution clear. The Ce_2O_3 was estimated by adding a fair excess of KHO to the solution and passing in a current of washed chlorine gas, which dissolves the La_2O_3 and Di_2O_3, leaving the Ce_2O_3 as a yellow precipitate. It was found necessary to again dissolve and treat with KHO and chlorine. This precipitate dissolved in HCl, largely diluted with water and the Ce_2O_3 precipitated as oxalate, filtered, washed, ignited, and weighed.

	I.	II.
Ce_2O_3 found—	22·72%	22·40%

The La_2O_3 and Di_2O_3 were estimated by difference, the Ce_2O_3 and ThO_2 present having been determined.

The ZrO_2 was determined in the filtrates, from the precipitation of the Cerium group with oxalic acid (B free from P_2O_5). Solution treated with an excess of HNO_3, and after all action had ceased, evaporated down nearly to dryness to decompose the oxalic acid. To the clear solution an excess of NH_4HO was added, warmed, and allowed to settle, the precipitate of Zirconia Fe_2O_3 Al_2O_3, filtered on to an ashless filter, washed, dried, burnt, and weighed.

The Fe_2O_3 and Al_2O_3 were estimated in a separate lot, and taken off the precipitate.

	I.	II.
Found—ZrO_2	15·44%	15·33%

The CaO and MgO were determined in the filtrate.

The Yttria was determined by preparing an oxalate precipitate of the earths from one gramme of the sand, dissolving in H_2SO_4, and to the clear solution adding an excess of tartaric acid and ammonia.

On long standing for some time a small precipitate was found equal to 0·16 per cent. of Y_2O_3.

The economic value of Monazite being principally its thoria contents, this sample appears to be of little commercial value.

The following are the analyses of some of the Foreign Monazites:—

Per Cent.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
P_2O_5	28·62	27·07	27·38	28·70	26·86	28·18	25·09	3·07	18·39
Ce_2O_3	32·52	25·82	67·40	31·30	24·80	33·54	33·64	6·20	22·42
La_2O_3	29·41	30·62		39·9	26·41	28·33	30·21	4·30	22·95
Di_2O_3	.....	.....	.....	.....	... ..	.....	.....	.....	.. ...
Y_2O_3	2·04	2·03	.....	.....	4·76	.....	.....	.....	·16
ThO_2	4·54	9·60	.....	.....	12·60	8·25	1·23	0·45	·46
SiO_2	1·51	1·85	.....	.....	·91	1·67	3·21	Sand consists mainly of zircons.	6·68
Al_2O_3	·22	·15	.....	.....	.....	.....	3·11		·14
Fe_2O_3	·36	1·01	·32	.....	1·07	.....	.....		2·08
FeO	.....	.....	.....	.....	.....	.....	.....		.....
MnO	.....	·08	1·24	.....	.....	.....	trace		trace
CaO	·84	·91	Tr	.....	1·54	.....	.....		1·32
MgO	.. ...	·03	.....	.....	·04	... ..	trace		trace
ZrO_2	.....	.....	.....	.....	.....	.....	.....		15·36
SnO_2	.....	.....	.....	.....	.....	.....	.....		9·03
PbO	.....	·58	.....	.....	... ..	.....	.....		.....
F.	.....	.....	4·35	.....	.....	.....	.....		.....
Ta_2O_5	.....	.....	.....	.....	.....	.....	.....		1·10
TiO_2	.....	.....	.....	.....	.....	.....	.....		.....
H_2O	·27	·35	some	.....	·78	·37	.....		·10

1 and 2. From Southern Norway. Analyst, C. W. Blomstrand.
3. From Karazfvt, Sweden. Analyst, F. Radowinski.
4. From Caravellas, Brazil. Analyst, H. Gorceix.
5. Ottawa, Co. Q. Analyst, Genth., Am. Journ. Sci., 1889, xxxviii, p. 203,
6. Burke Co., W.C. Analyst, Penfield, Am. Journ. Sci., 1882, xxiv, p. 250.
7. Gough Co., N. S. Wales. Analyst, W. A. Dixon, Min. N.S. Wales, Liversidge.
8. From Tooloom alluvial gold-fields, N.S. Wales. J. C. H. Mingaye, Geol. Records Surv., N.S. Wales, 1899, VI, p. 118.
9. Concentrates from beach sand, Ballina, Richmond River, N.S.Wales. J. C. H. Mingaye.

XXIII.—Notes and Analyses of Olivine-Basalt Rocks from the Sydney District (No. 1): by JOHN C. H. MINGAYE, F.I.C., F.C.S., Analyst, and H. P. WHITE, Assistant Analyst.

THESE analyses have been undertaken with a view of a thorough systematic description being furnished of the chemical composition of the rocks from this State, and and for compilation of the analyses for future reference and use of the Petrologist.

The chemical classification of the various constituents present are given in the order proposed by Pirrson, and advocated by Dr. Washington, as used by W. F. Hillebrand, Chemist to the United States Geological Survey.

The analyses have been conducted on the material free from the weathered portions.

We are indebted to our colleague, Mr. George W. Card, A.R.S.M., F.G.S., Curator and Mineralogist to the Department, for the following petrological notes :—

***A, B, C.**—Analcite-Basalts from Bondi and Canterbury.

These rocks have been thoroughly examined and analyses furnished in a paper given in the Records of the Geological Survey of New South Wales, so that there is no need to refer to them in this paper.

D.—Analcite-Olivine Basalt from Luddenham.

From an important dyke, some twelve feet wide, traceable across country for several miles, standing up as a wall.

The basalt is compact and aphanitic, with abundance of phenocrysts of olivine visible to the eye. Under the lens there are no traces of vesicular or amygdaloidal characters.

Under the microscope the rock is seen to consist of phenocrysts of olivine and purple augite set in a granular groundmass of augite, felspar, olivine, and magnetite, the whole being enveloped in a general mesostasis of analcite.

Olivine.—The phenocrysts are much cracked. In general they show incipient serpentinisation, but, occasionally, pseudomorphs occur. Indications of crystallographic form are not general. Granules occur in the groundmass.

Augite.—Automorphic, purple and pleochroic phenocrysts ; but occasionally parti-coloured with a grass-green nucleus. Granules and laths in the groundmass. The phenocrysts may form aggregates.

Felspar.—Lath-like microlites in the groundmass. Not at all conspicuous.

Apatite.—In long needles.

Magnetite.—Generally distributed in little crystals.

Analcite.—Abundant as an interstitial filling. It is colourless and isotropic, but may be altered to a dusky yellow product. It is traversed by black fibres, which may radiate from a centre and anastomose.

Biotite.—A very little is present.

The analcite shows much better in this basalt than in those from Bondi and Canterbury just referred to.

E.—Olivine-Basalt from Camden Park.

Holocrystalline, porphyritic. Phenocrysts of olivine and augite are seen in a groundmass of granular brown augite, lath-shaped felspar microlites, and magnetite.

Olivine.—Fresh with some serpentinisation.

Augite.—Brown and not noticeably pleochroic—one crystal shows complete idiomorphisism. It has a dusky nucleus, a brown peripheral band, and a pale-green intermediate zone. The felspar microlites tend to stream round the phenocrysts.

* Rec. Geol. Survey N S. Wales, 1902, VII, Pt. 2, pp. 93-101.

F.—Olivine-Basalt. Seal Bay (adjacent to Long Bay).

The solid rock was reached by means of a shaft sunk by some miners, who were under the belief that masses of compact blue quartzite resulting from the alteration of the sandstone in contact with the dyke were lode quartz. As usual in the Sydney district, the upper portions of the dyke had weathered into clay.

Under the microscope, phenocrysts of olivine and augite are seen to lie in a groundmass of granular augite, felspar microlites, and magnetite, with some streaky purplish glass (?).

Olivine.—Very fresh, with occasional incipient serpentinisation only. Automorphic, corroded and embayed by the base.

Augite.—Automorphic; pale purplish-brown in colour, and pleochroic. The slide examined contained a large exogenic fragment of altered purplish pyroxene.

G.—Olivine-Basalt. Hurstville.

The exact locality of this dyke is not known. The rock differs microscopically from that at Salt Pan Creek, Peakhurst.

Phenocrysts of olivine and augite in a base of granular augite, felspar laths, and magnetite, with some colourless isotroric material.

Olivine.—More or less automorphic, shattered, and corroded. Sometimes slightly serpentinised.

Augite.—Purplish-brown and pleochroic.

H.—Altered Dolerite (Diabase). Guildford, near Parramatta.

Holocrystalline and amygdaloidal, much calcite present.

Consists of granular brown augite, laths of fresh labradorite, and chloritic areas of a pale green colour, with a fibrous radial structure, and often enveloped by calcite and much iron ore. The iron ores comprise magnetite, and ilmenite with leucoxene.

I.—Olivine-Basalt. Rookwood.

Holocrystalline and porphyritic; but also slightly ophitic and approximating to dolerite.

Phenocrysts of automorphic olivine, augite, and magnetite are embedded in a groundmass of felspar microlites, granular augite, and magnetite.

Olivine.—Fresh, with occasional incipient serpentinisation along cracks and some serpentine pseudomorphs. It is corroded and invaded by the groundmass.

Augite.—Automorphic crystals, purple and strongly pleochroic. The colour is at times deeper, or almost confined to the margin.

Magnetite.—Conspicuous crystals in places, also as a dust over the olivine. The augite phenocrysts may be entirely wanting, and a little biotite may be present in the groundmass.

J.—Altered Dolerite (Diabase). Long Reef, Narrabeen.

A narrow dyke intersecting the shales of the Narrabeen Stage. It may be seen at low water standing up as a low wall. In places the rock is quite amygdaloidal. Under the microscope, phenocrysts of purplish-brown augite are seen, embedded in a groundmass of felspar laths, ophitic augite and chlorite. Much calcite is present in the form of amygdales.

K. Olivine-Basalt. Dundas Quarry, Pennant Hills.

A volcanic neck, intruding the Hawkesbury Series.

A compact black rock. Under the microscope small phenocrysts of fresh olivine are seen, embedded in a groundmass comprising two generations of felspar laths—some of which approximate to phenocrysts, minutely granular augite, and a speckled grey base, together with some interstitial, colourless, approximately isotropic material. Micro-sections are transparent on thin edges only.

L. Dolerite. Prospect Quarry, near Parramatta.

Holocrystalline, black, even-grained and somewhat compact. Ophitic and not porphyritic, consisting of augite, felspar, biotite, iron ore, and apatite.

Augite.—Slightly purple, but not distinctly pleochroic. Ophitic with regard to the felspar. Fresh, with some alteration, principally along cracks. At times it shows good prismatic forms and cleavage. Biotite may be enclosed by it.

Felspar.—Fresh labradorite.

Biotite.—Fairly abundant, often opaque, and intimately associated with the iron ores.

Iron Ores.—Much ilmenite with leucoxene; intimately associated with biotite. On examining some particles of the rock iron pyrites was observed.

Apatite.—Distinct; enclosed by all the other constituents.

Summary.—All these dykes, or otherwise, are intrusive in the Hawkesbury Series. By some authorities they would be grouped as follows:—

- Olivine Basalts
  - Analcite-bearing
    - Bondi.
    - Canterbury.
    - Luddenham.
  - Dundas.
  - Camden Park.
  - Rookwood.
  - Hurstville.
  - Seal Bay.
- Altered Dolerite (Diabase)
  - Long Reef.
  - Guildford.
  - Prospect.

The basalts from Bondi and Canterbury have already been proved to be analcite-bearing; also the olivine basalt from Luddenham. The chemical composition, and the isotropic matter that has already been noted in one or two of the others, *e.g.*, Hurstville, suggests that they may perhaps all prove to be of the same class or may very probably be found to contain nepheline.—G.W.C.

On boiling the finely-powdered material in each case for two minutes with dilute Nitric acid (1:40), and evaporating the clear solution down to dryness, gelatinous silica was obtained, thus showing the ready solubility of certain of the constituents present in the rocks by treatment with very dilute acid.

The solution in strong hydrochloric acid gave much iron, with lime and magnesia.

Analyses of Olivine-Basalt and Dolerite Rocks from Sydney District.

	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.	K.	L.
Silica (SiO_2) ..	43·39	43·48	41·10	43·54	46·51	41·62	42·48	38·12	44·54	41·22	45·88	43·06
Alumina (Al_2O_3)	16·67	16·53	14·82	15·61	15·27	15·49	14·70	14·11	16·44	15·60	17·16	16·31
Ferric oxide (Fe_2O_3)	3·47	3·42	2·35	3·20	2·50	3·41	3·96	3·58	2·00	1·99	3·03	5·40
Ferrous oxide (FeO)	8·80	8·91	10·38	8·64	8·92	9·38	9·24	7·43	9·75	8·95	7·57	7·61
Magnesia (MgO)	7·30	7·12	9·43	9·16	8·40	10·47	9·15	6·91	10·82	6·26	6·26	5·49
Lime (CaO)	8·79	8·88	10·56	8·88	9·12	9·74	9·08	11·40	9·16	9 96	7·20	9·37
Soda (Na_2O)	3·30	3·27	3·94	3·44	3·12	2·68	3·13	2·23	3·04	2·21	4·08	3·12
Potash (K_2O)	2·17	2·31	1·28	2·10	1·17	1·86	1·99	1·16	1·23	2·02	1·78	1·07
Water at 100° C.	·29	·31	·39	·32	·22	·31	·14	·58	·25	·68	·88	1·16
Water over 100° C.	2·67	2·69	2·31	2·56	1·21	2·16	1·34	2 71	1·53	1·87	3·17	2·93
Carbon dioxide (CO_2)	·39	·40	·26	·21	·61	·55	·94	9·60	·11	7·12	·60	1·36
Titanic dioxide (TiO_2)	2·20	2·35	3·20	1·81	2·20	1·88	2·38	1·12	·80	1·44	2·24	2·46
Vanadium pentoxide (V_2O_5)	·01	·01	trace	·01	·03	·02	·02	·02	·06	trace	·03	·05
Zirconium dioxide (ZO_2)	.....	.....	.....	absent	.....	absent	absent	.....	.....	.....	.....	.....
Phosphoric anhydride (P_2O_5)	·41	·44	·19	·40	·33	·23	·39	·40	·44	·37	·19	·32
Sulphur trioxide (SO_3)	·19	·21	·09	·10	·11	·09	·10	·24	·07	·50	·09	.....
Chlorine (Cl)	·02	·03	trace	trace	·04	·02	·02	trace	absent	·03	·02	·02
Fluorine (F)	... ..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Ferric disulphide (FeS_2)	.....	.....	.. ...	absent	.....	.....	.....	.....	... ..	.....	.....	·26
Chromium sesquioxide (Cr_2O_3)	trace	trace	trace	trace	·02	trace	·01	·01	·02	·01	·01	.....
Nickel protoxide (NiO)	trace	trace	trace	·04	·03	·03	·06	absent	·04	trace	·05	·06
Cobalt protoxide (CoO)	trace	trace	trace				minute trace	absent		trace		
Copper protoxide (CuO)	.....	.....	.....	·01	minute trace	.....	·01	.....	minute trace	.....	.....	.....
Manganous oxide (MnO)	·19	·15	·14	·26	·05	·08	·11	·18	·05	·06	·24	·23
Barium oxide (BaO)	·02	·02	·06	·24	·04	·22	·12	·07	·02	·19	·13	·02
†Strontium oxide (SrO)	trace	trace	trace	.....	trace	trace	trace	trace	trace	trace	trace	trace
** Lithium oxide (LiO_2)	present	present	present	present	present	absent	present	absent	present	present	present	present
	100·28	100·53	100·50	100·53	99·90	100·28	100·27	99·87	100·37	100·48	100 61	100·30
Specific gravity of rock	2·943	2·941	2·994	2·953	3·014	.....	3·027	2·903	3·000	2·919	2·898	2·814

Analyses A, B, E, G, I, and L by J. C. H. Mingaye; C, D, F, H, J, and K by H. P. White.

† Less than 0·01 %; presence determined by flame reaction and spectroscope.

** Presence determined by spectroscope.

A and B, Analcite-Basalt. Bondi.
C. ,, ,, Fernhill, Canterbury.
D, ,, ,, Luddenham. No gold or silver detected.
E, Olivine-Basalt. Camden Park.
F, ,, ,, Seal Bay, adjacent to Long Bay.
G. ,, ,, Hurstville.
H, Dolerite. Guildford.
I, Olivine-Basalt. Rookwood.
J, Dolerite. Long Reef, Narrabeen.
K, Olivine Basalt. Dundas Quarry, Pennant Hills.
L, Dolerite. Prospect Quarry. No gold or silver detected.

XXIV.—Descriptions of Two new Plants from the Tertiary of New South Wales—*Pteris abbreviata* and *Grevillea darlingioides*: by HENRY DEANE, M.A.

Plates XLV–XLVI.]

I.—*Pteris abbreviata*, sp. nov.

[Plate XLV.]

THE portions of fronds preserved exhibit a type of venation characteristic of *Pteris*; the small veins branching from the midrib to the margin of the pinnæ are once or twice forked.

The original frond was almost bipinnate, the principal pinnæ being lobed or again pinnate towards the base of the frond. In this respect the fossil strongly resembles the living *Pteris ensiformis*, Burm. The secondary pinnæ, where they exist, are five-eighths of an inch in length; the lobes of the primary pinnæ are of irregular length, from, one quarter of an inch upwards, and from ovate to almost linear in shape; the terminal lobes of the pinnæ and that of the apex of the frond reach a length of one and a half inch.

The resemblance in character to *Pteris ensiformis*, Burm., above mentioned, is very striking, the chief difference being that in the fossil the lobes and secondary pinnæ are shorter.

Figs. 1 and 2 show the apices of the pinnæ, or, perhaps, even the termination of a frond. Fig. 4 appears to be a pinna from the upper part of the frond, while fig. 3 represents a portion of one of the larger pinnæ from near the middle or base of the frond. Fig. 5 shows a fertile lobe with recurved margin concealing the sori.

From Elsmore, New England.

II.—*Grevillea darlingioides*, sp. nov.

[Plate XLVI.]

Leaf about nine inches in length and six inches in breadth, deeply pinnatifid. The lobes are two in number on each side, the lower ones being the longest and three and a half inches long and one and a half inch broad, ovate lanceolate in outline. The base of the leaf is ovate and tapered into the peduncle. The sinuses between the lobes are narrow and almost acute.

The midrib is stout and strong, lateral or secondary veins run up the centre of the lobes, and each pair is approximately opposite. The tertiary veins branch at an angle of about seventy degrees, follow a double curve and reach the margin, or nearly so and are situated about half an inch from one another. The impressions of the finer reticulated veins have not been preserved.

At the base of the leaf a pair of other leaves have become superimposed in such a way as to produce the appearance of being basal pinnæ or stipules to the larger leaf. A closer inspection proves, however, that their position is fortuitous, as they lie in a plane above the larger leaf.

The general aspect of the pinnatifid leaf described is that of some *Proteaceæ*, and there can be little doubt that the original belonged to that natural order. The living plants, the leaves of which most resemble the fossil, are *Grevillea hilliana*, F.v.M., *Stenocarpus sinuatus*, Endl., and *Darlingia spectatissima*, F.v.M. In general shape they all more or less correspond, but the sinuses in the fossil are sharp like those of *Darlingia* and *Grevillea*, and not open like *Stenocarpus*. The tertiary veins reach the margin or approximately so, and in this respect are like *Darlingia* and not like the other two where they meet an intramarginal vein at some distance from the margin; on the other hand they are distant from one another as in *Stenocarpus*. I have chosen the name of the larger and probably older genus for the generic name; the specific name is given on account of the many points of resemblance to *Darlingia*.

From Vegetable Creek, New England, collected by T. W. E. David, B.A., F.R.S.

XXV.—An Unusually Large Form of *Rhizophyllum*, lately discovered in New South Wales: by R. ETHERIDGE, Junr., Curator of the Australian Museum, Sydney.

[Plate XLVII.]

Mr. CHARLES CULLEN, Collector to the Geological Survey, has lately obtained two specimens of an usually large *Rhizophyllum* from Boree Creek, near Molong. It is proposed to call this interesting coral *Rhizophyllum enorme*. The following are the characters of the species:—

*Rhizophyllum enorme**, sp. nov.

[Plate XLVII.]

Sp. Char.—Corallum elongately pyramidal, compressed, straight, slightly expanded above, obtusely pointed and truncated below, or simply truncated; lateral angles moderately sharp; section semi-oval, plano-convex. Dorsal surface with a low degree of convexity; ventral flat, both longitudinally and transversely,

* Enormis—e very large or immense.

or very slightly bowed longitudinally. Calice shallow, pit-like in the centre; dorsal edge curved and slightly dipping; ventral edge somewhat concave. Position of the counter septum very apparent on the ventral surface; rugæ (costæ, *auct.*) very numerous and fine, visible on the ventral surface. Internal structure entirely vesicular, the component vesicles irregular both in form and size, very oblique near the walls, but becoming much less so towards the centre of the corallum; septal spines are here and there visible on the convex faces of the vesicles. Epitheca very strong, consisting of bundles of concentric laminæ, giving to both surfaces a rugged and uneven appearance, the intersection of the rugæ and laminæ causing a minute decussation or tesselation; stolon bases few, scattered along the lateral angles.

Obs.—The outline of the two specimens differs to some extent, the larger is more elongately-pyramidal and less conical than the smaller; it is also more compressed in comparison to its other measurements. The following data will at once explain this :—

	Corallum, length.	Calice, greatest diameter.	Base, greatest diameter.	Calice, least diameter.	Base, least diameter.
Large corallum	$2\frac{6}{8}''$	$2\frac{3}{8}''$	$1\frac{6}{8}''$	$1\frac{1}{8}''$	$\frac{6}{8}''$
Smaller corallum	$2\frac{3}{8}''$	$2''$	$\frac{5}{8}''$	$1''$	$\frac{3}{8}''$

The form of the smaller individual is more akin to that of *R. gotlandicum*, F. Roemer, whilst that of the former is suspiciously like that of *Platyphyllum sinense*, Lindström.*

It is most unfortunate that neither the septa in the calice, nor the operculum are preserved. The floor of the calice is only visible in the smaller specimen, and is much worn, exposing naturally weathered sections of the uppermost blister-like vesicles. Both the dorsal and ventral edges of the calice in each specimen are much worn.

The base in the larger coral is wide transversely, narrow fore and aft, flat, and truncate. In the smaller corallum it is obtusely drawn out, small, truncate, and with a slight dorsal inclination.

In a transverse section prepared for the microscope, the component vesicles are lenticular, but of very variable size, and some seem to exhibit septal ridges (or spines?) on their convex faces. In a longitudinal section the same features are observable, the peripheral vesicles being the larger.

Generic identity oscillates between *Rhizophyllum* and *Platyphyllum*,* but in the absence of the septal characters it is very difficult to come to a decision on this important point. In the meantime, this interesting form is provisionally referred to the former genus.

Loc.—Boree Creek, Portion 3 Parish Cudal, Co. Ashburnham (*C. Cullen*).

* Lindström, Richthofen's China, 1882, IV, Abth. 4, p. 68, t. 5, f. 8.

XXVI.—The Fructification of *Schizoneura australis*, Eth. fil.: by R. ETHERIDGE, Junr., Curator of the Australian Museum, Sydney.

[Plates XLVIII, XLIX.]

IN 1893 I described a portion of a plant from the roof of the No. 1 Seam at the Bulli Colliery, referring it to *Schizoneura*, but I pointed out that the specimen did not exhibit any tendency to form pseudo-leaves, nor was the articulation of the stem clear.* The Bulli coal seam forms the top of the productive Upper Coal Measures of New South Wales.

I subsequently figured† a fragment of a similar plant from the second Cremorne Bore, Shell Cove, Port Jackson, obtained at a depth of one thousand two hundred and seventy-four feet six inches, in the olive-green shales of the unproductive measures between the Bulli Seam and the Hawkesbury Sandstone. This specimen distinctly exhibits a pseudo-leaf.

Schizoneura remains have now been again met with towards the completion of the sinking of the Birthday Shaft of the Sydney Harbour Collieries Company at Balmain, at a depth of two thousand eight hundred and seventy feet. The specimens are numerous, and exhibit all characteristic features of *Schizoneura*—pseudo-leaves, nodes, and veins. The leaves attain a length of two and three-quarter inches, and are slightly curved, and accuminate to a semi-obtuse point. The veins vary from four to nine, and the nodes average one inch apart.

The chief interest, however, centres itself in one specimen exhibiting a fertile shoot, for the loan of which I am indebted to Mr. J. Jarvie, Assistant Manager of the Sydney Harbour Collieries Company. As Seward‡ says that "fertile shoots" of *Schizoneura* are "unknown," this will form a decided advance in our knowledge of the plant's structure.

The specimen in question (Pl. XLVIII, fig. 1) consists of the terminal portion of a branch, with portions of four leaves, one on the right and three on the left. Between the right-hand leaf and the first of the three left is a narrow, upright, linear stalk, giving support to two cone-like strobili.

It may be once for all stated that through compression little more can be made of these cones beyond their size, and the fact that their surfaces have a faint tesselated appearance as if divided into polygonal figures arranged in oblique series. Like that of the leaves, the surface of these cones is carbonised. One cone is thirty

* Records Geol. Survey N. S. Wales, 1893, III, Pt. 3, p. 76.
† *Ibid.*, 1894, IV, Pt. 1, p. 32, t. 7, f. 1.
‡ Fossil Plants, 1898, I, p. 292.

millimetres long by eight millimetres wide, pod-shaped, and slightly curved; the other is twenty millimetres long by seven wide, and, although similar in shape, not curved. The cones seem to be attached to the stalk by very short stalks.

These cone-like fertile shoots seem to be quite different to the loose strobilus of *Phyllotheca deliquescens*, Göpp., consisting of peltate sporangiophores attached to the stem between whorls of sterile leaves, figured by Schmalhausen, nor do they resemble the cone-like terminations attached to stems bearing a *Phyllotheca*-like foliage, lately described from the Upper Coal Measures of Newcastle by myself.* On the contrary, there is a decided resemblance to the conical group of sporophylls of *Equisetum* proper, *e.g. E. maximum*, Lam.,† or *E. sylvaticum*, Linn., and other species figured by Schimper, arising in the first instance from the form of the strobili in our *Schizoneura*; and in the second, that I really believe the tesselated appearance of the latter represents the outward polygonal markings on the strobilus of *Equisetum*.

Here, however, the strobili are developed in pairs and not singly as in *Equisetum*.

At this point I would call attention to a spike, figured by Heer, from Siberia, associated with stems and leaves, called by him *Phyllotheca sibirica* as possessing the general appearance of our fossil. It is uncertain whether or no Heer's fructification really appertains to the associated stems and leaves, for they are not attached to the latter, but only in juxtaposition.

Seward's remarks on this point seem to have a marked bearing on the subject of the present fossil. He says, "several of his (Heer's) specimens appear to possess leaf sheaths more like those of *Equisetum* than *Phyllotheca*"; and, again, "so far as it is possible to judge from an examination of Heer's figures and a few specimens from Siberia in the British Museum . . . . . there appears to be little evidence in favour of separating the fossils described as *Phyllotheca Sibirica* from *Equisetites*." If the fertile axis figured by Heer is in reality that of the plant fragments known under the foregoing specific name, and if Seward's suggestion be the solution of the identity of *P. sibirica*, then, I ask,—Is it not possible that the fertile spike of *Schizoneura australis*, now figured, displays a closer relation to the Equisetum-group than it does to the Phyllotheca group? I quite apprehend that the state of preservation of the *Schizoneura* cones is too unsatisfactory to permit of an answer in the slightest degree conclusive, but the suggestion may serve as a basis for future investigation.

* Records Austr. Mus., 1901, IV, No. 1, p. 1, t. 1 and 2.
† Seward, Fossil Plants, 1898, I, p. 246, f. 52 A.

XXVII.—On the Occurrence of Nepheline in Post-Triassic Basalts of the Hawkesbury Sandstone Area.

By GEORGE W. CARD, A.R.S.M., F.G.S., Curator and Mineralogist.

THE presence of primary analcite in certain of these basalts has already been recorded,* and has since been noticed in the Luddenham dyke, where it is well displayed.

The occurrence of nepheline has been known in one case for some years, and suspected in others; but has not as yet been definitely recorded. As the evidence is now accumulating, it seems desirable that it should be made available. This evidence is both direct and indirect in character. The former consists in the ready detection of nepheline in basalts from two localities; while the indirect evidence depends upon a study of the chemical analyses published in the present issue of these Records by Messrs. J. C. H. Mingaye and Harold P. White, Analysts to the Survey.

DIRECT EVIDENCE.

Nepheline-Basalt from The Peak, Upper Burragorang.

The Peak is a mountain carved by denudation out of Permo-Carboniferous strata, and capped by a few feet of Hawkesbury Sandstone with a little nepheline-basalt at the summit. It is possible that one or more of the neighbouring peaks are similarly capped. The basalt is greyish-black in colour, and has a finely-granular fracture. It is quite fresh, and shows an abundance of olivine.

Microscopic Characters.—Phenocrysts of olivine and greenish-brown pyroxene lie in a groundmass of pyroxene laths, a little brown glass, and granules of magnetite and olivine, with nepheline.

Olivine.—Much corroded; and quite fresh, but for slight serpentinisation along cracks. An association with picotite was noticed.

Pyroxene.—Greenish-brown and slightly pleochroic. The crystals are occasionally automorphic. Zoning occurs; and the border may be darker than the interior. A large part of the interior is sometimes traversed by ramifying strings of glass.

Nepheline occurs in the groundmass as colourless material, with feeble double refraction. Rectangular sections are occasionally seen, sometimes in nests. At times it may completely envelop a granule of olivine. Inclusions are present.

Magnetite.—As small crystals, copiously scattered through the rock.

Inclusions.—An important aspect of this rock is the presence of conspicuous fragments, exogenic in character.† These consist of pyroxene and picotite, sometimes in mutual association. A deep zone of alteration surrounds the nuclei of fresh pyroxene. The picotite also has an opaque marginal zone of alteration. Felspar being practically absent, this rock is a true Nepheline-Basalt.

* Rec. Geol. Survey N. S. Wales, 1902, vii, Pt. 2, pp. 93-101.

† The occurrence of basic inclusions in the Post-Triassic basalts of the Sydney District has been already referred to in a recent number of these Records. (Vol. vii, Pt. 2, p. 89.)

Nepheline-bearing Basalt from North Dural.

This is found on the property of the late Mr. Hugh Turner (G. Acre's fifteen hundred acres), a little to the south of Rose Trig. Station. It occurs just at the junction of the Hawkesbury Sandstone with the overlying Wianamatta Shales. Although only exposed in two very small openings from which a few tons of stone have been quarried, the extent of the alteration undergone by the shale and sandstone which can be readily seen in the neighbouring creek, road, and orchard, leads me to believe that we are dealing with a small neck. The existing exposure reveals about twenty feet across of sound olivine-basalt. The rock is very compact.

Microscopic Characters.—Under the microscope small phenocrysts of fresh olivine are seen in a microlitic fluidal groundmass of felspar, augite, magnetite, and nepheline.

Olivine.—Corroded and shattered phenocrysts; perfectly fresh.

Augite.—As granules in the groundmass, hardly ever attaining conspicuous dimensions.

Felspar.—Abundant microlites in the groundmass.

Nepheline.—As feebly doubly-refracting areas in the groundmass. Rectilinear outlines are seldom seen.

This is, therefore, a normal olivine-basalt containing nepheline, thus differing from the Burragorang rock.

INDIRECT EVIDENCE.

The chemical composition of the Post-Triassic basalts has been investigated by Messrs. Mingaye and White, whose results are tabulated on page 230.* A study of these results throws much light upon the nature of the magma from which they proceed and also upon their individual constitution. Thus, the silica percentage† ranges from 46 down to 41, and the magma must therefore be regarded as an ultra-basic one. Further, the alkalies are high, as shown by the following table:—‡

Weight percentage of—	Bondi.	Fernhill.	Camden Park.	Luddenham.	Seal Bay.	Rookwood.	Hurstville.	Dundas.	Warramalong Mountain.	Mount Tomah.
Soda	3·30	3·94	3·12	3·44	2·68	3·04	3·13	4·08	4·22	3·61
Potash	2·17	1·28	1·17	2·10	1·86	1·23	1·99	1·78	1·80	1·80
Total Alkalies	5·47	5·22	4·29	5·54	4·54	4·27	5·12	5·86	6·02	5·41

* Analyses of the nepheline-bearing varieties of Burragorang and Dural have not as yet been made.

† The basalts having broken through hundreds of feet of sandstone, grains of quartz are frequently found in them, the percentage of silica given by the bulk analysis being thereby slightly increased.

‡ Certain of the results tabulated on page 230 are not dealt with, as the rocks proved to be considerably altered, and that from Prospect at times contains analcite amygdales. An analysis has also been made of the Warramalong basalt by Mr. H. P. White, and of the Mount Tomah basalt by Mr. J. C. H. Mingaye. Both these are flows.

It will be seen that in the case of the Warramalong rock the total alkalies reach six per cent., and the soda alone exceeds four. By calculation,* it can be readily seen that in the Camden Park rock alone is there sufficient silica to combine with all the alkalies in the proportion required for felspar; felspathoids must, therefore be present in the others. Further, Messrs. Mingaye and White state (page 229) that in every case the finely-powdered material gelatinised readily in very dilute acid, indicating the presence of analcite or nepheline. A more careful calculation shows, further, that in certain cases—the Luddenham dyke, for instance—the silica available will not avail to combine with the whole of the soda as analcite, so that nepheline must be present. In other cases, it is not at present possible to say whether the felspathoid is analcite or nepheline or whether both are present.

In certain of these rocks a little biotite occurs, which will absorb some of the potash. It may thus be regarded as proved that the basaltic eruptions characterising the Hawkesbury Sandstone area, from its present northern boundary to Burragorang—and most probably further south,—and from the coast to the Blue Mountains, emanated from a common magma, whose characteristics were, (*a*) low silica, (*b*) high alumina, (*c*) high alkalies. The crystallisation of this magma in dykes and surficial masses has resulted in analcite-bearing and nepheline-bearing olivine basalts, and in one case of a true nepheline-basalt. The deep-seated representatives of these rocks may be confidently expected to be of a very basic type—a result already anticipated from a study of the exogenic igneous fragments contained in the basalts. It is, however, extremely improbable that denudation has anywhere yet exposed the *massif*.

XXVIII.—A Preliminary Note on the Structure of Mount Lindsay. By E. C. ANDREWS, B.A., Geological Surveyor.

[Plate L.]

MOUNT Lindsay of the maps,† in the Macpherson Range, is a remarkable mesa or flat-topped residual of a lofty plateau, formerly stretching from the Main Dividing Range, and gradually decreasing in height to the coast.

Plate L represents the upper portion of Lindsay. The plane of view is on a long spur of the mountain, one thousand feet above the Richmond River. The mountain summit is about four thousand one hundred feet above sea-level, and the almost inaccessible cliffs forming the crown are nearly one thousand feet in height.

* The method of calculation suggested by American Authors in a "Quantitative Classification of Igneous Rocks," Chicago, 1903, has been followed.

† W. H. Traill.—Mount Coot-tha Reserve, Queensland Geographical Journal, 1901-1902, XVII, p. 43.

The base of the mountain stretching from the seven hundred to the one thousand seven hundred feet level, consists of trachyte flows, tuffs, basalt, sandstones, shales, coal-seams, and ironstone concretions. From the one thousand seven hundred feet to the three thousand two hundred feet level the mountain rises in exceedingly rough escarpment form, and consists of dense fine-grained basalts, tuffs, and sedimentary rocks, all horizontally disposed. The summit consists of columnar pitchstones and agglomerates, reposing on a bed of friable yellow pitchstone ash. This pitchstone series represents the remnant of once extensive coulées. The vertical jointing of the pitchstone is very pronounced, appearing rudely columnar from a short distance. The rock has a dark base, porphyritic with quartz and felspar. The remarkable feature of the rock is the perlitic nature of the quartzes.

In Trias-Jura times, great sheets of trachyte were poured out over a sinking area in which coal, sandstones, and conglomerates were being laid down. Over these, basalt floods alternated with tuffs and sandstones; then, in later geological periods, immense coulées of pitchstone were extruded. With these are associated incoherent tuffs and huge agglomerates of pitchstone.

The evolution of the mesas, of which Mount Lindsay is the most remarkable example, is simple. The vertical jointing of the pitchstone coulées induced deep narrow cañons in the plateau during the initial stages of erosion attendant on Tertiary uplift. When, however, the underlying incoherent tuffs were discovered, "sapping" occurred, and rapid retrogression of the cliff faces ensued, the columnar structure preserving vertical faces to the rapidly receding walls. The underlying dense basalts were in turn attacked by the streams, and found by them to alternate with soft clays, tuffs, sandstones, and lower-lying hard trachytes. As a result of this commingling of hard and incoherent structures, horizontally disposed, wholesale degradation of the plateau followed,—a fact which puzzles the topographer when viewing this mesa-country the first time from a distance, since great unreduced masses of the plateaus exist both to the west, south, and north of the area under consideration. These latter, however, consist for the most part of homogeneous acid granite types and indurated slates, unassociated with any horizontally bedded incoherent beds. Where the hard thick trachyte layers attained considerable dimensions, as at Tooloom, rapid lateral corrasion received a decided check, and large dome-shaped masses* became the expression of those forces which had reduced the surrounding sandstones, shales, tuffs, and associated columnar lavas to broad low-lying plains.

A study of the locality illustrates the rapid enroachment by the Richmond on the Clarence Basin.

The following petrographical notes on an interesting volcanic glass have been supplied by Mr G. W. Card, A.R.S.M., from a paper by Mr. W. F. Smeeth.†

* *e.g.*—The Crown, Edinbro' Castle, and North Obelisk.
† Proc. Roy. Soc. N. S. Wales for 1894, XXVII, pp. 306-320, fols. 44-46.

Perlitic Pitchstone from the Tweed River, Macpherson Range.—Black glassy matrix, uniformly studded with numerous phenocrysts of quartz and felspar, averaging two or three mm. in diameter. Semi-vitreous lustre and conchoidal fracture. The perlitic structure is pronounced.

Quartz occurs as bi-pyramidal crystals, corroded and yellow-stained, and traversed by cracks emulating perlitic structure.

Felspar occurs as glassy tabular crystals of sanidine, with smaller crystals of albite.

Under microscope, the rock is clear and fresh; some glass inclusions are present (negative crystals). The felspar is also clear and fresh, with great cavities filled with glass, some being negative crystals.

Hypersthene occurs in small distinct grains of prismatic habit. Much corroded magnetite grains scattered through the rock, also included in and surrounding hypersthene, from which it may have been derived.

The *glass* itself is thoroughly vitreous, but filled with microlites and crystallites. These are like black twisted lines following the lines of flow and vortex motion of the magma. High powers are necessary to resolve these apparent lines. The microlites are plagioclase (lime-soda variety). The crystallites are globulites, axiolitically arranged.

Apatite, zircons, and sapphires are also present.

The accompanying analysis of the Mount Lindsay rock was carried out by Mr. J. C. H. Mingaye:—

SiO_2	75·51
Al_2O_3	14·30
Fe_2O_3	1·01
CaO	1·81
MgO	·24
K_2O	2·89
Na_2O	1·21
H_2O	2·84
	99·81

The base contained K_2O ·78, Na_2O ·14, and therefore is relatively richer in soda than the phenocrysts.

PLATE XXVII.

Description of photo-micrographs illustrative of the igneous series of the Cambewarra Mountains.

Figs. 1 and 2. Augite-mica-Lamprophyre from neck (a).

These show automorphic *diopside* and *plagioclase*, with *biotite*, *magnetite*, and *apatite*. The areas lettered *f* in the key are occupied by clustered plagioclase; they seldom represent individual crystals.

Objective, 1 inch photographic. Eyepiece not used. Plane light. x 22.

Fig. 1. Rock specimen 5069; micro-slide 2273 A.
Fig. 2. Rock specimen 5019; micro-slide 2222 A.

Fig. 3. Trachyte from the flow.

A residual mass of *hornblende*, *biotite*, and *diopside*, all highly altered, lie in an obscure groundmass.

Objective, 1 inch photographic. Eyepiece not used. Plane light. x 25.

Rock specimen 5033; micro-slide 2226B.

Fig. 4. Mica-Lamprophyre from neck (b).

An abundance of richly-coloured *biotite*, with automorphic *diopside* and *plagioclase*, and *magnetite*. The letter *f* indicates areas of felspar for the most part.

Objective, 1 inch photographic. Eyepiece, 1 inch photographic. Plane light. x 27.

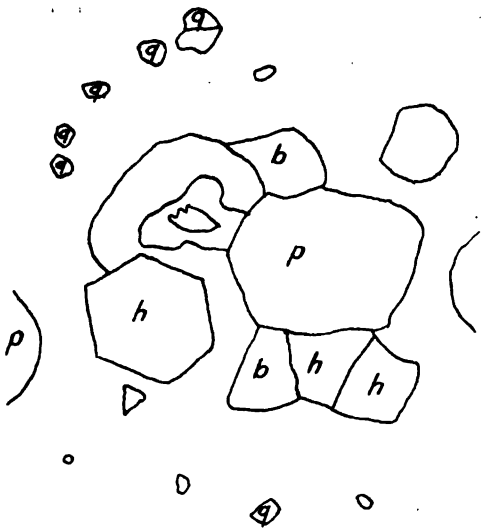
Rock specimen 5028; micro-slide 2217B.

For diagram sketches see other side.

INDEX TO MICRO-PHOTOGRAPHS.

1

2

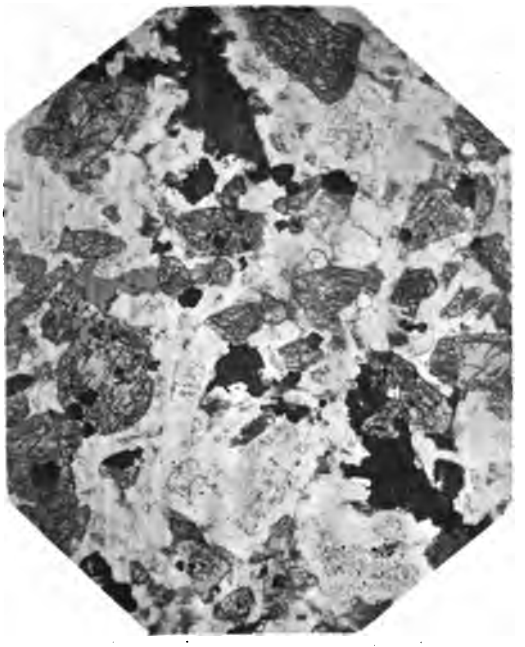


3

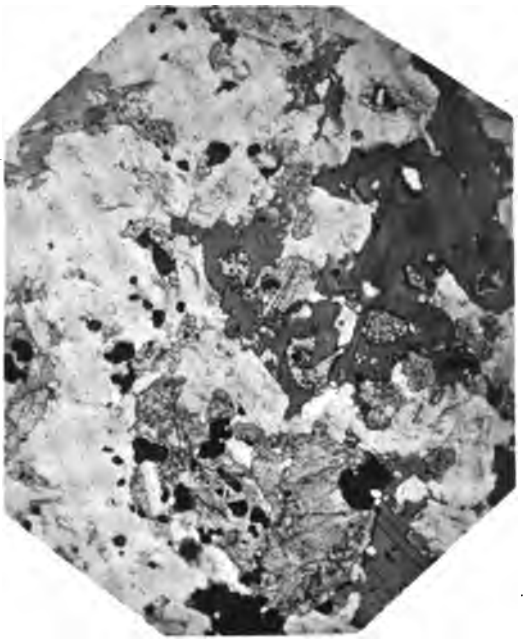
4

a—Apatite. *b*—Biotite. *f*—Felspar. *h* Hornblende.
m—Magnetite. *p*—Pyroxene. *q*—Quartz.

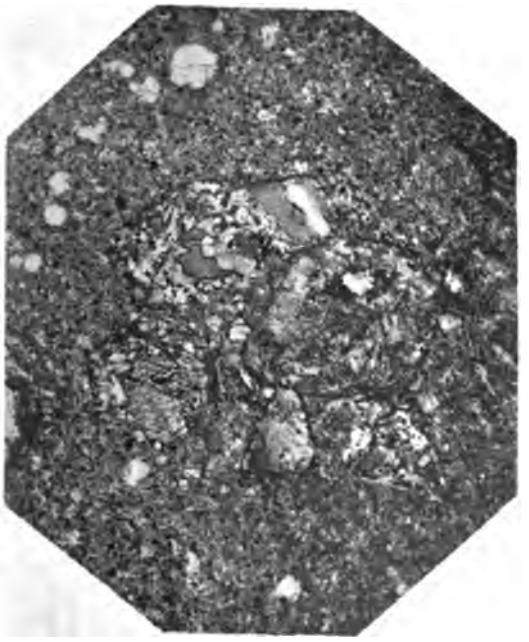
Photo-lithographed by
W. A. Gullick, Government Printer,
Sydney, N.S.W.



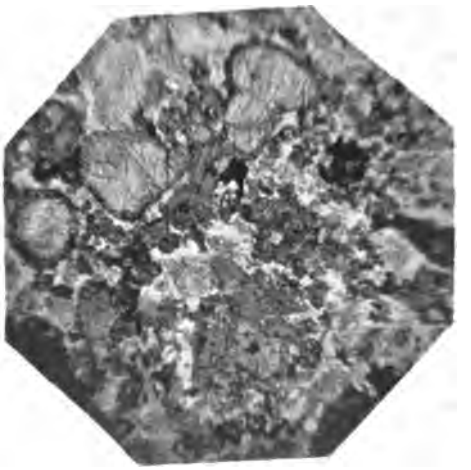
1



2



3



4

PLATE XXVIII.

Diagrams (after Brögger) for comparing the molecular constitution of the rocks whose analyses are tabulated on page 138. The molecular ratios have in each case been calculated to 200.

Fig. 1. Hornblende-Lamprophyre Dyke, Cambewarra.

Fig. 2. Lamprophyric Diorite, Cambewarra.

Fig. 3. Augite-mica-Lamprophyre, Cambewarra.

Fig. 4. Trachyte, Cambewarra.

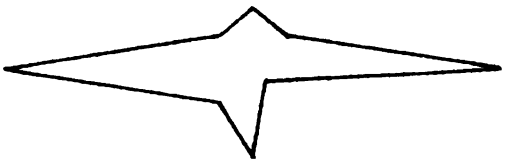
Fig. 5. Augite Latite.

Fig. 6. Quartz Banakite.

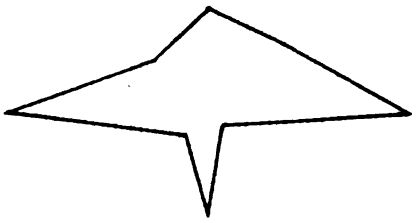
Fig. 7. Vulsinite.

Fig. 8. Trachytic dykes (an average), Cambewarra.

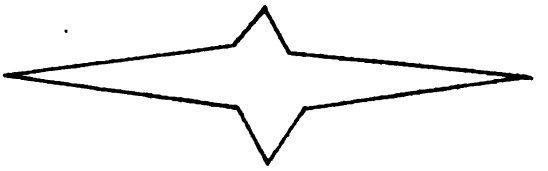
1



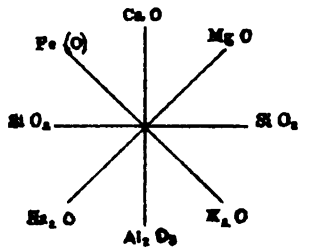
2



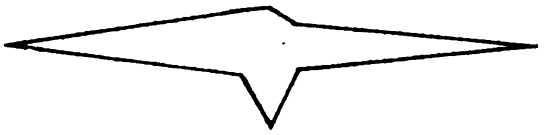
3



4

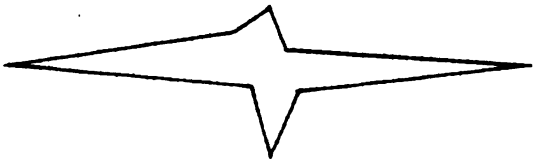


KEY

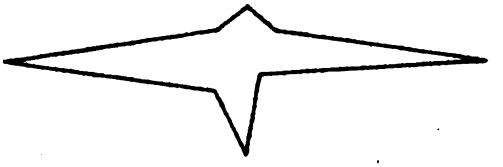


5

6



7



8

HARVARD GEOLOGY LIBRARY

PLATE XXIX.

Geological Map (with section) of the Cambewarra Range.

Scale—80 chains to 1 inch.

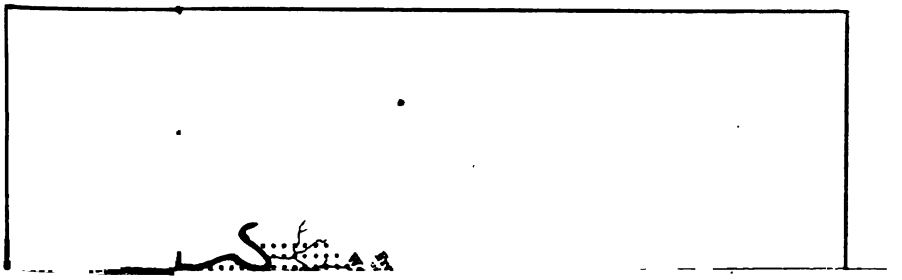


PLATE XXX.

Geological Sketch Map of Good Dog Mountain, near Nowra.

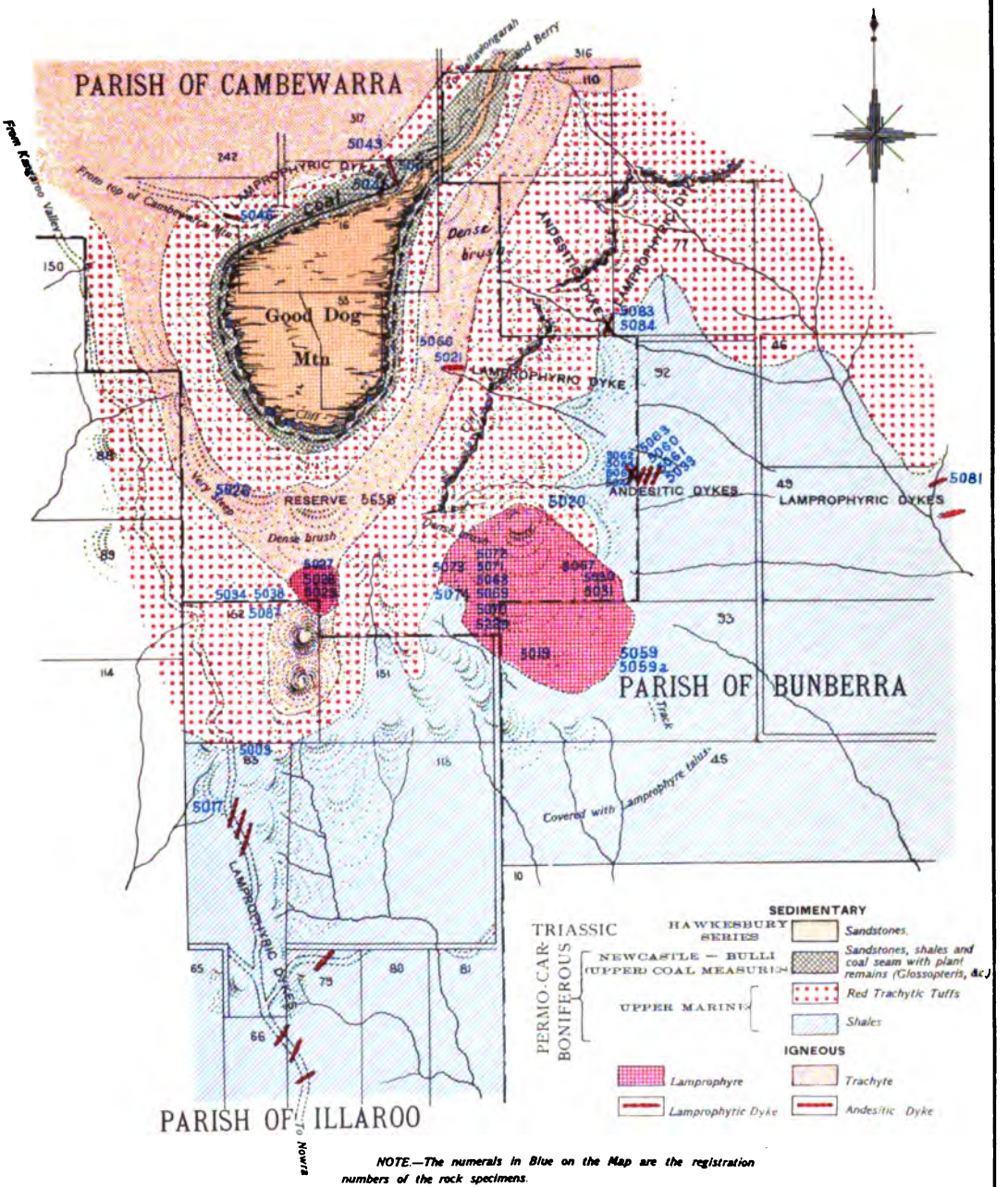
GEOLOGICAL SKETCH MAP OF GOOD DOG MOUNTAIN

NEAR NOWRA

By J. B. JAQUET, A.R.S.M., F.G.S., Geological Surveyor, and L. F. Harper, Field Assistant.

Prepared under the direction of E. F. PITTMAN, A.R.S.M., Government Geologist, Department of Mines and Agriculture, Sydney, 1903.

Scale 0 10 20 30 40 Chains



NOTE.—The numerals in Blue on the Map are the registration numbers of the rock specimens.

Photo-lithographed by

PLATE XXXI.

Tertiary and Cretaceous Plains at Tenterfield. The general level in the plane of vision is the Stannifer Plain; the heights beyond are residuals of the Mole and Bolivia Plains.

PLATE XXXII.

Fig. 1. Hillgrove Gorge, cut in the Sandon peneplain.

Fig. 2. Differential erosion of acid and basic lavas. Gloucester Buckets, Barrington River.

FIG. 1.

FIG. 2.

PLATE XXXIII.

Fig. 1. Weathering of Columnar basalt, Guy Fawkes.

Fig. 2. Uralla. Columnar basalt.

FIG. 1.

FIG. 2.

PLATE XXXIV.

Baker's Creek, Hillgrove.

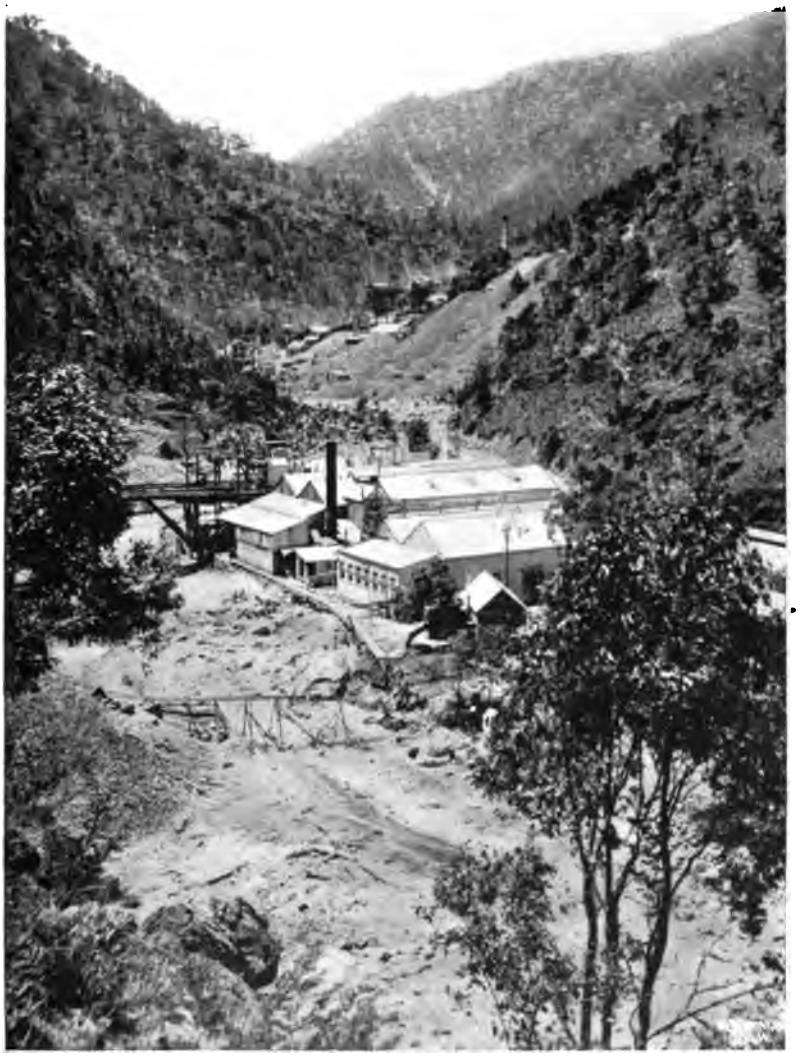


PLATE XXXV.

Fig. 1. Development of the Hunter River at Belltrees. The flat-topped mountains are residuals of the Guyra Plain.

Fig. 2. Uralla. The point of view is on the Sandon Plain; the hills are remnants of the Guyra and Mole Plains.

FIG. 1.

FIG. 2.

PLATE XXXVI.

Fig. 1. Diamond Head, showing coastal topography.

Fig. 2. Smoky Cape, Trial Bay, showing effect of marine erosion in northern areas.

Fig 3. Tweed water-gap at Byangum.

Fig. 4. Guyra Plain and Lagoon, 4,300 feet above sea level.

FIG. 1.

FIG. 2.

PLATE XXXVII.

Fig. 1. Weathering of slate, Apsley.

Fig. 2. Mt. Warning, showing mature stage of plateau dissection.

Fig. 3. Weathering of granite blocks.

Fig. 4. Flood Plains of the Tweed.

FIG 1.

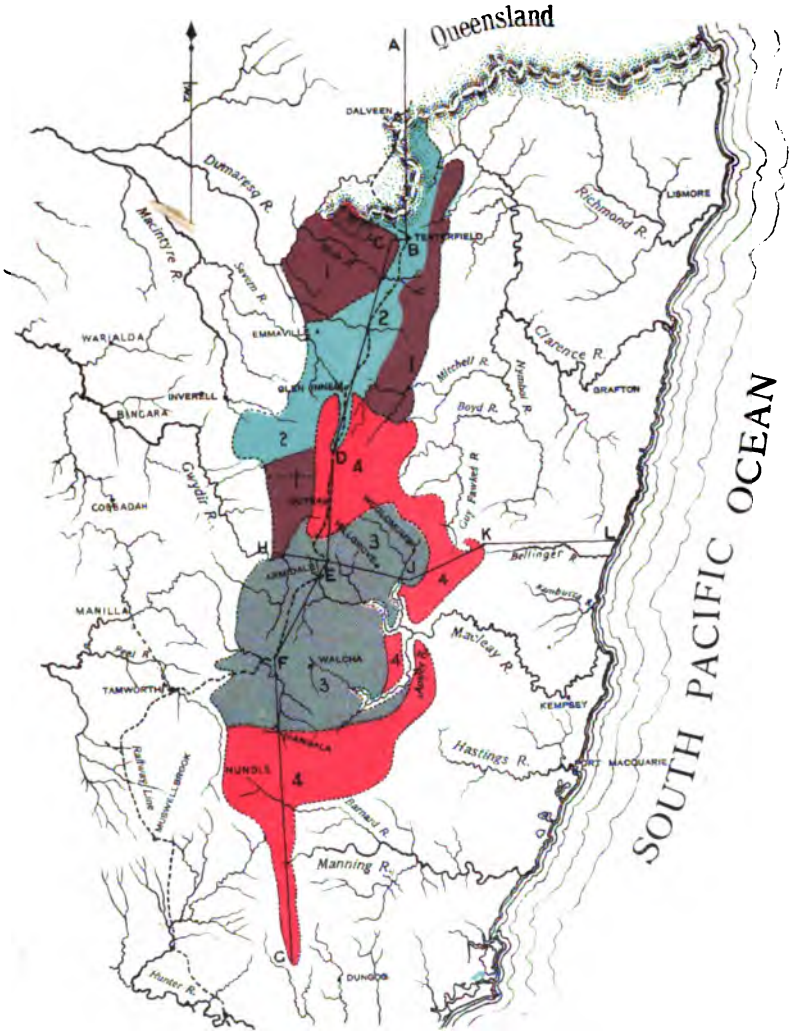
FIG. 2.

PLATE XXXVIII.

Sketch Map of the New England Plateau.

SKETCH MAP
of the
NEW ENGLAND PLATEAU

Scale 0 — 25 — 50 Miles



1. *Mole tableland*	*Nearly 4,000 feet high, with residuals of the Bolivia Plain*	*(Granite)*
2. *Stannifer Plain*	*3,200 feet high*	*(Granite and slate)*
3. *Sandon Plain*	*3,500 feet high*	*(Granite and slate)*
4. *Guyra Plain*	*4,300 feet high*	*Basalt)*

The boundaries of the tableland are shown approximately only
The country slopes thence east and west

15050

Photo-lithographed by
W. A. Gullick, Government Printer,
Sydney, N.S.W.

PLATE XXXIX.

Sketch section along the New England Plateau (on line A–G).

Sketch section from Armidale to the Coast (on line H–L).

Sketch Section along the New England Plateau (on line A to C)

Sketch Section From Armidale to the Coast (on line H to L)

Showing slope of Sandon Plain and the residuals of Bolivia and Guyra Plains

The Sandon and Stannifer Plains contain numerous isolated patches of basalt showing the development of these plains before the basalt overflows

Granite, slate, and basalt boundaries only approximate.

15050

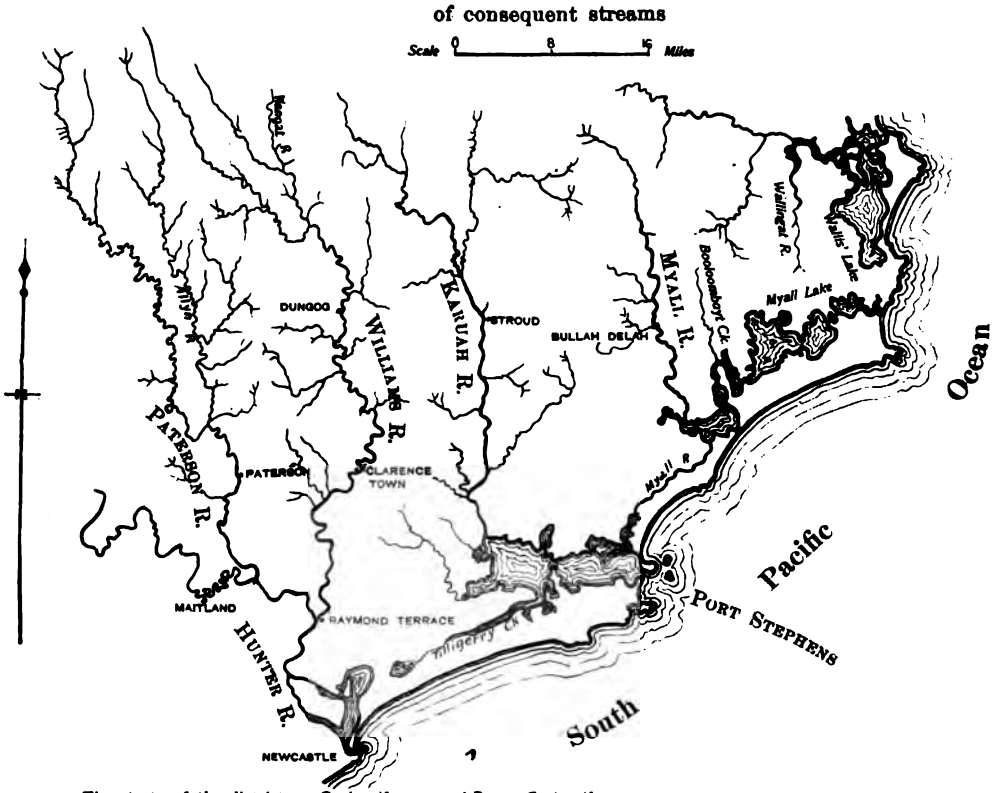
Photo-lithographed by
W. A. Gullick, Government Printer,
Sydney, N.S.W.

PLATE XL.

Map of Port Stephens District, showing development of subsequent and absence of consequent streams.

MAP
OF
PORT STEPHENS DISTRICT

Showing great development of subsequent, and absence of consequent streams



The strata of the district are Carboniferous and Permo-Carboniferous, and the prevailing strike is approximately meridional

Gently swinging beaches are common, a feature accentuated by the recent elevation

16050

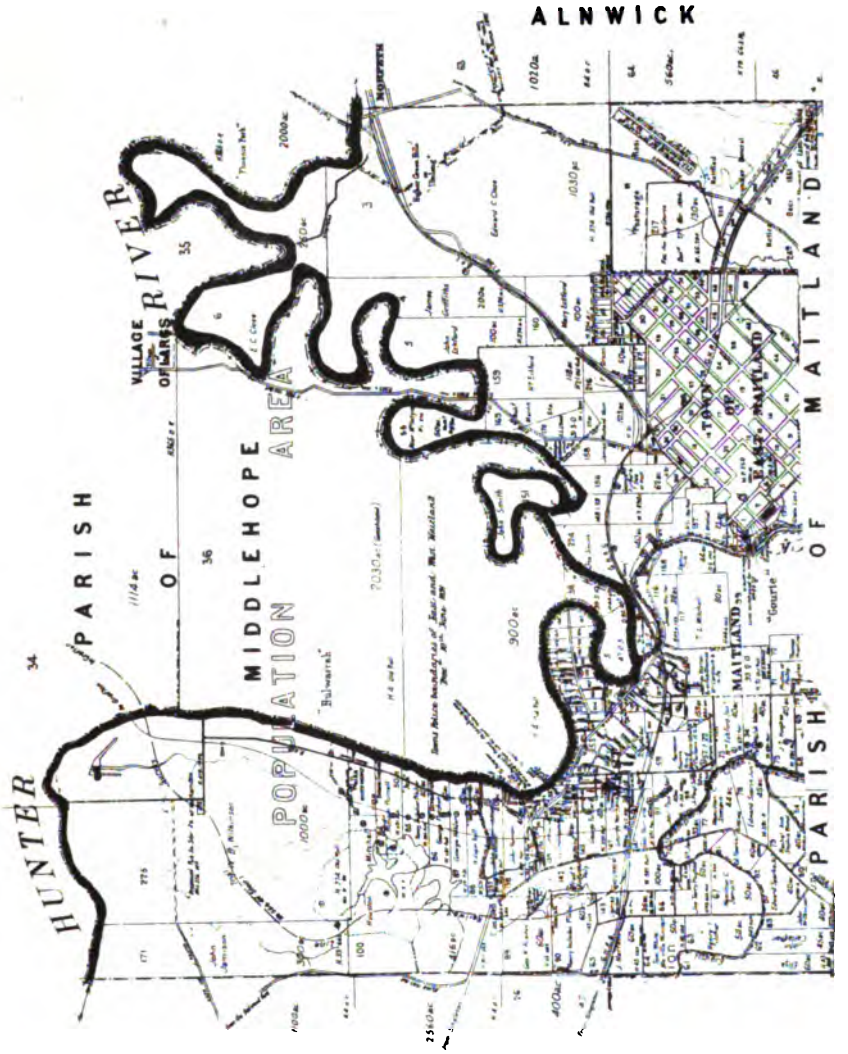
Photo-lithographed by W. A. Gullick, Government Printer, Sydney, N.S.W.

PLATE XLI.

Meanders of the Hunter River at Maitland.

Meanders of the

HUNTER RIVER AT MAITLAND



PARISH OF COSFORTH

16050

Photo-lithographed by
W. A. Gullick, Government Printer,
Sydney, N.S.W.

PLATE XLII.

The Mount Browne Meteorite, with scale of inches.

PLATE XLIII.

The Mount Dyrring Meteorite, with scale of inches, showing kernels of olivine.

.....3 inches.....

PLATE XLIV.

Glassy Meteorites ("Obsidianite") from New South Wales.

Photographed to true scale.

Fig. 1.—A, B, C. Bull and Dampor Creek, Tumbarumba.

Fig. 2.—A, B, C. Bell's Creek, Braidwood.

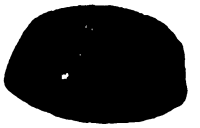
Fig. 3.—A, B, C. Liverpool.

1A

1B

1C

2A



2B

2C

3A

3B

3C

PLATE XLV.

Pteris abbreviata, *sp. nov.*

Fig. 1. Portion of frond, showing terminal pinnule.

Fig. 2. Portion of a pinna.

Fig. 3. „ „ „

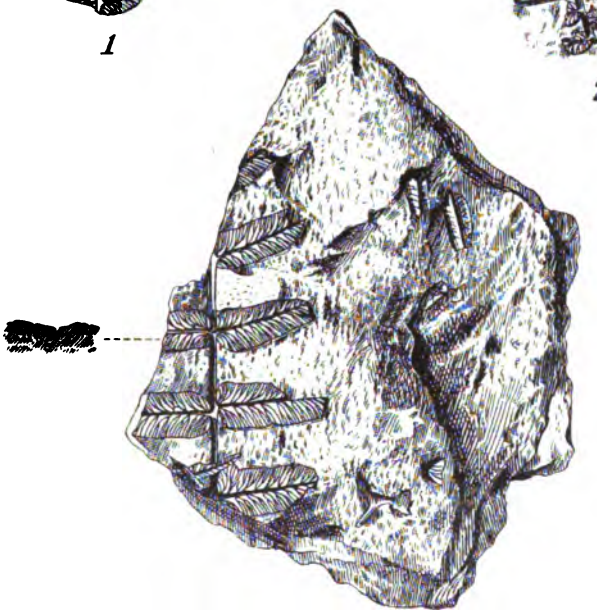
Fig. 4. „ „ „

Fig. 5. Portion of later pinnule, slightly enlarged.

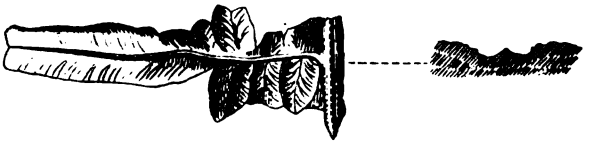
Drawn from nature by P. F. Hammond.

1

2



3



4

5

P.T.Hammond del.

15050

Photo-lithographed by
W. A. Gullick, Government Printer,
Sydney, N.S.W.

PLATE XLVI.

Gervillia darlingoides, *sp. nov.*

PLATE XLVII.

Rhizophyllum enorme, *Eth. fil.*

Fig. 1. The larger form, dorsal view.

Fig. 2. The same, side view.

Fig. 3. The same, view of the calice, with the blister-like vesicles and sub-central depression.

Fig. 4. The smaller form, dorsal view.

Fig. 5. The same, ventral view.

Fig. 6. The same, side view.

Fig. 7. The same, view of the calice, exhibiting weathered vesicles and sub-central depression.

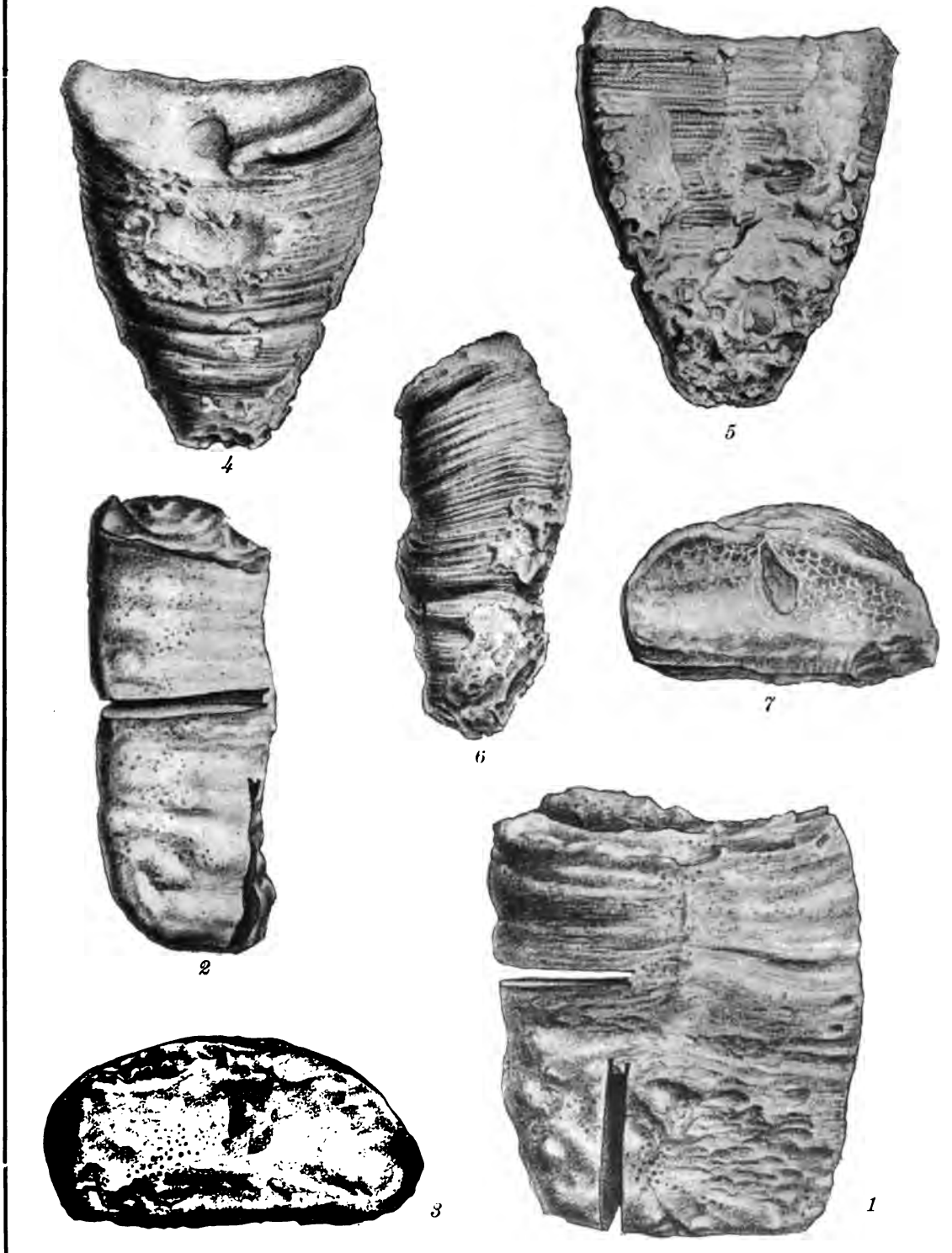

4
5
6
7
2
3
1

PLATE XLVI.

Gervillia darlingoides, *sp. nov.*

PLATE XLIX.

Schizoneura australis, *Eth. fil.*

PLATE L.

View of Mount Lindsay.

DEPARTMENT OF MINES AND AGRICULTURE, SYDNEY.

RECORDS

OF THE

GEOLOGICAL SURVEY OF NEW SOUTH WALES.

Vol. VII.] SEPTEMBER, 1904. [Part 4.

XXIX.—Notes on some of the Dykes and Volcanic Necks of the Sydney District, with Observations on the Columnar Sandstone: by M. Morrison, Field Assistant.

[Plates LI—LIVa.]

The area embraced under the title comprises the greater part of the County of Cumberland, and portion of the County of Camden. It extends, roughly, from Hornsby on the north to Thirlmere on the south, and from St. Mary's on the west to the coast line. The following observations refer mainly to the volcanic intrusions in the southern and western portions.

The occurrences of igneous rock in the Sydney District are limited to intrusions of basaltic rock as dykes and plugs, and volcanic agglomerates and breccias as necks, while irregularly rounded blocks of gabbro, enclosed in the basalt, are met with in the Dundas Quarry near Pennant Hills.

Some of these, more particularly Prospect, attracted attention shortly after the foundation of the Colony. This hill is one of the most marked geological features, as on many occasions from the early settlement days up to the present it is referred to by different writers.

In 1826 P. Lesson wrote* :—

"Prospect Hill is an elevated ridge composed entirely of dolerite, the first of which is surrounded by sandstone."

* For reference see Bibliography, App. II, p. 272.

In 1827 P. Cunningham said* :—

. . . the land formed by the decomposition of the whin being clearly discernable from the fine grassy sward it exhibits, and the crops it returns to reward the husbandman. It is sometimes found in mere specks, as I might say, covering some two or three acres, while no other specimens can be seen for many leagues round. There is a patch of this kind near 'One Tree Hill,' on the right of the Parramatta River as you proceed from Sydney, yielding luxuriant crops of whatever may be sown upon it."

There is some difficulty in associating this reference with any of the known occurrences of igneous rock, but it most probably relates to what is now known as the Dundas Quarry, near Pennant Hills, which is referred to by several writers.

The dykes, of which there are a considerable number along the coast line between the South Head of Port Jackson and Cape Banks at the north of Botany Bay, have been mapped and described by Mr. G. A. Waterhouse, B.Sc. The unpublished results of his examination have been kindly supplied to the Geological Branch, and are incorporated in the recently issued "Geological Sketch Map of the country in the vicinity of Sydney." The dykes described by Mr. Waterhouse are, without exception, intrusive in the Hawkesbury Sandstone, and generally much decomposed. Particular efforts have been directed towards obtaining details of those occurrences of igneous rock mapped by the Rev. W. B. Clarke, and shown on the geological map published in the 4th edition of his "Remarks on the Sedimentary Formations of New South Wales, 1878."

The dykes are fairly numerous over the area, while the necks recorded are few and scattered, and though a large number of dykes are recorded in this paper, and plotted on the geological map, it is more than probable that only a very small proportion has been brought under notice. It is hoped that these brief records may stimulate further search, and a more detailed examination than the Writer was in a position to make.

The main geological features of the Sydney District are comprised in the three stages of the Hawkesbury series respectively known as Narrabeen Shales, Hawkesbury Sandstone, and Wianamatta Shales of Triassic Age, while recent deposits, and numerous volcanic occurrences—basaltic dykes, plugs, and agglomerate necks—are scattered throughout the area. The beds of the Narrabeen Stage are composed of chocolate shales, grits, and sandstone, and are exposed mainly along the coast at the northern and southern extremities of the area. They underlie the Hawkesbury Sandstone, and in the vicinity of Sydney attain a thickness of 1896 feet, as proved in the boring operations for coal by the Sydney Harbour Colliery

* For reference see Bibliography, App. II, p. 272.

Company at Cremorne and Balmain. Some fine cliff sections of the shales of this division occur on the coast at Narrabeen. Near Long Reef they dip beneath sea-level and reappear within a few miles of Otford on the South Coast.

The Hawkesbury Sandstone, or Sydney Sandstone of Dana, occupies nearly the whole of Sydney proper, and forms most of the surface in the south-eastern and north-eastern portions of the area under discussion, together with practically the whole of the coast line from Wattamolla to Narrabeen. The beds exhibit abundant examples of false bedding and weathering, and their thickness at Cremorne has been ascertained to be one thousand and twenty feet. The leading characteristics of the formation can best be obtained along the cliffs between the points above mentioned.

The Wianamatta Shales are composed chiefly of beds of shale, with occasional calcareous grits and sandstone, and occupy the major portion of the area, extending over almost the whole of that part west of the Northern and Southern Railway lines. There is often marked contemporaneous erosion at the junction of these beds with the underlying Hawkesbury Sandstone. In places they occur only as thin cappings on the sandstone, while going south from Hornsby they thicken considerably, and near Picton it was estimated by the Rev. W. B. Clarke that they attain a maximum thickness of eight hundred feet, and here the grits and sandstone are more conspicuous. The material for the manufacture of bricks and pottery round Sydney is mainly derived from these beds.

Recent marine deposits have formed extensive flats, rising to only a few feet above high-water mark, around a number of the bays and inlets along the coast. Around Botany Bay these accumulations are spread over a considerable area. Recent Æolian deposits cover a large extent of country along the coastal region between Port Hacking and Sydney Harbour, and a good illustration of these wind-blown sand hills may be observed between Bondi Beach and Rose Bay. Recent alluvial deposits occur in several places, especially on the low-lying lands.

I am indebted to Mr. G. W. Card, A.R.S.M., Curator and Mineralogist, for the preparation of Appendices I and II, and also for much valuable assistance.

The Geological Survey is indebted to Mr. J. B. Henson, C.E., for supplying information with reference to dykes intersected in the Sydney sewerage excavations.

It is proposed to describe each occurrence separately under headings, and at the conclusion a few remarks on characteristic features are given. The Roman numerals assigned to the dykes are those used on the recently published Geological Sketch Map. The occurrences, for descriptive purposes, are grouped into three sections :—

A.—Dykes in which the rock is sound or only partially decomposed.

B.—Decomposed dykes.

C.—Volcanic necks.

DETAILED OBSERVATIONS.

A.—*Dykes in which the rock is sound or only partially decomposed.**

No. LXIV.—**Peakhurst**—Lack's Estate. Portion 125, Ph. St. George, Co. Cumberland. Olivine-Basalt intruding Wianamatta Shales. Strike N. 40° E. Width about ten feet. Dip not obtained. Some years ago quarrying operations were carried on along the dyke, but the excavations are now partly filled in. The adjacent shales are highly altered in places. This intrusion is believed to be a continuance of No. LXII, which crosses the railway line near Belmore Station, but owing to the land in the vicinity being under cultivation, the dyke could not be traced for any great distance in that direction.

No. LXXIV—LXXIVB—**Rookwood**—Immediately south of the park in Joseph-street, and about three-quarters of a mile south of the Railway Station. Ph. Liberty Plains, Co. Cumberland. At this spot there are three parallel dykes within a distance of half a chain, intruding the Wianamatta Shales.

No. LXXIV.—This is the southernmost dyke of the three. Strikes east and west. Width about two feet. Dips north at about 87°. Near the eastern extremity of the exposure the dyke has bifurcated, forming two small dykes about one foot wide, and running parallel in an easterly direction.

No. LXXIVA.—The middle dyke is situated about twenty feet north from the above dyke. Strikes east and west. Width about four feet. Dip south at about 87°.

No. LXXIVB.—The northernmost dyke is separated from A by about two feet of altered clay shales. Strikes east and west. Width about three feet. Dip vertical. Quarrying operations have left a large excavation about ten chains long, by about half a chain wide and ten feet deep, to mark the presence of these intrusions. Owing to the presence of water in the excavation, the dykes could only be examined in the face at the eastern end of the quarry, where the rock is much weathered. Loose pieces of sound basalt were obtained close by. The metamorphism of the shales in the vicinity of these intrusions is a very noticeable feature. About the centre of the quarry the shales for about eighteen inches on each side of the dykes, and for about one chain in length, are converted into lydian stone, while at other points along the line the alteration is hardly appreciable. At the eastern end of the quarry the two feet of shales between dykes A and B, where one would expect to find intense induration, are only blackened and slightly hardened. The dykes could not be traced beyond the actual workings although the ground slopes away to the west for some distance.

* The arrangement of the dykes adopted is purely geographical.

No. LXXVI, LXXVIc.—**Guildford**—about three-quarters of a mile S.S.W. of the Railway Station, on Whittaker's Estate. Por. 99, Ph. St. John, Co. Cumberland. There are four dykes apparently parallel within a distance of about two chains, intrusive in the Wianamatta Shales. In two instances the igneous rock is very much decomposed.

No. LXXVI.—The main dyke of amygdaloidal Dolerite, a very calcareous rock, has a slightly sinuous course trending N. 40° E. Width eight to ten feet. The dip is not regular, but is north-westerly, generally at a high angle. The dyke has been opened out for a distance of about ten chains, and a large amount of stone taken out for road metal. The shales along the line of contact are, as a rule, not appreciably altered.

No. LXXVIc.—Situated about one chain north westerly-from the main dyk . The rock is a very compact Olivine-Basalt. This dyke has been exposed by trenching, but at the time of my visit the excavation was full of water, and in consequence no particulars were obtained. I was informed that it is about five feet wide, and runs parallel with the main dyke. Specimens of rock were obtained from the tip close by, and are quite distinct in character from those collected from the larger intrusion.

No. LXXVII.—**Wentworthville**—close to the Prospect Road, about one and a half miles S.W. of Wentworthville Railway Station. Por. 62, Ph. St. John, Co. Cumberland. Olivine-Basalt intruding the Wianamatta Shales. The strike is N. 25° E., and width apparently from four to five feet. The dip could not be ascertained. The dyke was worked some years ago for road metal, and as a result its position is now indicated by a large excavation, but owing to the growth of vegetation, and to the quantity of *débris* in the cavity, the rock is now concealed. A quantity of slickensided calcite is scattered about the old workings, but there is no evidence available as to the position it occupies in relation to the dyke. The shales in the immediate vicinity of the intrusion are considerably altered, being blackened and, in places, highly indurated. The dyke was not observed beyond the quarry.

No. LXXVIII.—**Smithfield**—about half a mile north of Kenyon's Bridge. Por. 154, Ph. Prospect, Co. Cumberland. Olivine Basalt intruding Wianamatta Shales. Strike N. 25° E., and width about three feet. The dip could not be ascertained. The adjacent shales are slighlty altered along the line of contact. Quarrying operations have been carried on along the dyke for a distance of about six chains.

No. LXXIX.—**Minchinbury**—about two miles south of Rooty Hill Railway Station. Por. 15, Ph. Melville, Co. Cumberland. Analcite-bearing Olivine-Basalt intruding the Wianamatta Shales. The dyke traces a slightly sinuous course with a general bearing N. 45° E., and at one point along the line takes a turn N. 60° E.

It varies in width from four to eight feet. The dip could not be ascertained. As in other instances the metamorphism of the sedimentary rocks in the vicinity is very irregular. At one point for a distance of about fifteen feet the shales are highly indurated for about four feet on either side of the dyke, while in other places, even along the contact, the alteration is hardly appreciable. A feature of interest in connection with this dyke, in common with Nos. CVII, CIX, and CXVI, is the interrupted outcrop. In one instance the dyke apparently pinches out, and in a short distance reappears about fifteen feet to the east of the direction of the original line, but still preserving the same strike. In the absence of good exposures it is difficult to account for this, but it may be explicable on the assumption that the dyke swings to the east, and does not rise to the present surface between the exposed points, or it may be that the different exposures represent the extremities of two distinct dykes. The only other alternative is the possibility of a fault, but there is no evidence of any in the neighbourhood. The course of the dyke is marked for a distance of about two miles by a series of short shallow trenches, the result of old quarrying operations, which, if continued on the same line, would cross the main Western Road, near the Eastern Creek.

No. LXXX.—**Rooty Hill**—about three-quarters of a mile S.E. of the Railway Station, and a few chains south of the Rooty Trig. Station. A few loose pieces of basalt were obtained here, but no evidence as to the mode of occurrence is available.

No. LXXXII.—**Riley's Quarry**—about two and a half miles N.W. of Parramatta —on Oakes' Estate. Por. 153, Ph. St. John, Co. Cumberland. Olivine-Basalt intruding the Wianamatta Shales, and striking N. 25° E. Dip nearly vertical, and width apparently about seven feet. A considerable amount of alteration of the adjoining sedimentary rocks has taken place, the sandstone in some places being converted into quartzite. In some of the sandstone bands the rock close to the dyke has assumed a prismatic structure, the prisms being very short, and only about an inch in diameter. More detailed particulars concerning this occurrence could not be obtained owing to the excavation, which is the result of old quarrying operations, being filled with water. The dyke was not observed beyond the old workings.

No. LXXXV.—**Bankstown**—on the northern side of the Sydney-Liverpool Road, near the fourteen mile-stone. Por. 53, Ph. Liberty Plains, Co. Cumberland. Altered Doleritic Basalt intruding the Wianamatta Shales. No basalt is exposed *in situ* in this instance, and the only indication of the presence of a dyke is a very shallow trench, about four feet wide, and about ten chains long, with some boulders of basalt in the bottom. The shales forming the walls are slightly indurated. Some years ago quarrying operations were carried on for road metal, and from the nature

of these old workings, together with the surroundings, there is little room for doubt that the basalt occurs as a dyke, and that the samples obtained are part of it. The strike is N. 45° E.

No. CI.—**Bankstown**— on southern s de of the Sydney-Liverpool Road, and about two chains S.W. of No. LXXV. Strike N. 45° E., and apparently about three or four feet wide. The dyke has been opened out at intervals for a distance of about fifteen chains, but the dip could not be ascertained owing to the walls of the workings having fallen in. The shales along the contact are slightly indurated.

No. CIV.—**Plumpton**—Lamb's Quarry—about two miles north from Mount Druitt Railway Station. Por. 15, Ph. Rooty Hill, Co. Cumberland. Olivine-Dolerite dyke intruding the Wianamatta Shales, and striking N. 45° E., with a north-west dip at 85°. Width nine to twelve feet. It is only exposed for a few chains where quarrying operations have been carried on. The adjoining shales are highly indurated in places along the line of contact.

No. CV.—**Lethbridge's Quarry**—close to the Tregear Trig. Station, and about one and a quarter mile N.E. of St. Mary's Railway Station. Por. 105, Ph. Rooty Hill, Co. Cumberland. Altered Dolerite dyke intruding the Wianamatta Shales. Strike N. 45° E., and dip N.W. at 80°, and width about six feet. It has been opened out to a depth of five or six feet at intervals for a distance of nearly a quarter of a mile, but very little of the igneous rock is now exposed owing to the trenches being partly filled in. The shales along the contact are slightly indurated and blackened. Although the dykes, Nos. CIV and CV, are not exposed beyond the workings, it is probable that they are connected, and it is possible that they are an extension of No. CVII.

No. CVII.—**St. Marys**—about two and a half miles S.W. of the Railway Station, on the Frogmore Estate. Ph. Claremont, Co. Cumberland. Olivine-Dolerite, a greenish-black rock, intruding the Wianamatta Shales. The dyke has a slightly sinuous course with a general trend N. 40° E., and a vertical dip. Width eight to twelve feet. It can be traced with interruptions for a distance of about one and a half miles, and at the southern extremity it makes a bend to the west. There are numerous breaks in the continuity of the outcrop, and in several instances the dyke appears to pinch out, outcropping again in a very short distance, from ten to twenty feet to the east or west of the original line, still maintaining the same strike. Owing to the limited exposures, as in No. LXXIX, the evidence available is no guide as to the cause. For a considerable distance the course of the dyke is along the top of a prominent ridge, and it is marked by a nearly continouus trench, the result of quarrying operations. The adjacent shales are highly indurated in patches along the contact, and, generally, the zone of alteration does not extend more than three or four feet on either side of the intrusion. In some places the shales are only blackened.

No. CIX.—**Luddenham**—close to the Public School and Cemetery. Ph. Bringelly, Co. Cumberland. Analcite-bearing Olivine-Basalt intruding the Wianamatta Shales. In places the dyke is a very conspicuous feature, outcropping along the top of a rather prominent ridge, which probably owes its preservation to the presence of the igneous rock. It is from six to nine feet wide, and strikes N. 48° W., with a south-westerly dip at about 85°. In places the igneous rock appears to be rudely prismatised, and in one small exposure where some quarrying has been done, two very thin clayey partings, parallel to the walls of the dyke, may be observed cutting the intrusive mass into three almost equal divisions. This is probably due to jointing, as there is no evidence of two distinct intrusions, and samples obtained from each division were examined microscopically by Mr. G. W. Card, who states that they are identical. The dyke outcrops strongly, and can be traced with little difficulty for three or four miles. Breaks in the outcrop, similar to those described in Nos. LXXIX and CVII, also occur. The adjacent shales are highly altered in places along the line of contact, patches of almost true lydian stone being exposed at several points. For about five chains on the southern side of the Anchau Trig. Station the surface is composed of basalt boulders, which have probably been shed from the dyke, and rolled down the slopes of the ridge. Quarrying operations have been carried on at several points along the dyke.

No. CX.—**Minto**—about a quarter of a mile N.N.W. of the Public School, close to the Main Southern Road. Por. 30, Ph. Minto, Co. Cumberland. An Olivine-Basalt dyke intruding Wianamatta shales. Strikes north and south. Width three feet. Dip west at 85°. Quarrying operations have exposed the dyke for a distance of about one and a half chains, and to a depth of from ten to fifteen feet. It can only be traced for a few chains beyond the quarry workings, owing to the land in the vicinity being under cultivation. Metamorphism of the shales extends for about eighteen inches on each side of the intrusive mass, and in some places the induration is intense, pieces of almost true lydian stone being obtained, but generally the alteration is not very marked. The quarry has been worked intermittently for road metal, but of late years nothing has been done beyond clearing away the loose material in the vicinity.

No. CXIV.—**Razorback Range**—near Picton. On the southern ascent of the range at the N.W. corner of Por. 117, Ph. Picton, Co. Cumberland. Dyke—decomposing—intruding the Wianamatta Shales, and striking N. 30° W., with a south-westerly dip at 60°. Width about two and a half feet. The intruded beds of shale and sandstone are indurated for about a foot on either side of the dyke, which is apparently not exposed beyond the road cutting.

No. CXV.—**Razorback Range**—near Picton. Por. 119, Ph. Picton, Co. Camden. Basaltic dyke, apparently from three to four feet wide, intruding the Wianamatta Shales, and striking N. 30° W. The dip could not be ascertained. A series of

shallow trenches, the result of old quarrying operations, indicate the course of the dyke for a distance of about ten chains. The adjacent shales do not appear to be altered to an appreciable extent.

No. CXX.—**Razorback**—Por. 123, Ph. Picton, Co. Camden—on the top of the range. Loose pieces of basalt were picked up here, but there is no evidence as to their point of origin.

Nos. CXVI-CXVIII.—**Douglas Park**—in the railway cutting, about one mile northerly from the station. Ph. Camden, Co. Camden. There are four dykes exposed within a distance of fifteen chains. In one instance the igneous rock has decomposed into a yellowish clay. The dykes are intrusive into the Wianamatta Shales. In each case the sedimentary rock is altered in close proximity to the intrusion, being slightly indurated in places, but generally only discoloured.

No. CXVI.—Southernmost dyke, about five and a half chains south of the forty-four mile railway peg. Hard compact basalt. Bearing N. 35° W., and dipping south-westerly at 77°. Width three and a half feet. The dyke has been opened out at intervals for about one and a half miles, and crosses the Main Southern Road about half a mile north of the Douglas Park Public School. There are numerous breaches in the continuity of the outcrop.

No. CXVII.—About half a chain northerly from No. CXVI. Decomposing rock. Strike N. 35° W. Dip south-westerly at 77°, and width about three feet nine inches. It does not appear upon the surface, but it is probably an extension of this dyke which is exposed in the cutting on the Southern Road, close to No. CXVI at that point.

No. CXVIII.—Situated about twelve chains north of No. CXVI. Partially decomposed basaltic dyke, bearing N. 35° W., and dipping south-westerly at 80°. Width two feet three inches. It is not exposed beyond the railway cutting.

No. CXIII.—**Camden Park Estate.** Por. 3, Ph. Camden, Co. Camden. Basalt has been quarried for road metal. Operations have ceased for some considerable time, but a quantity of the basalt is still scattered about in the vicinity. These old workings consist of several small circular excavations within an area of a third of an acre, but at present owing to the growth of vegetation there is only one very small exposure of the igneous rock *in situ*. The enclosing strata are Wianamatta Shales, which in places are highly indurated. No other intrusion has been seen within some distance of this quarry, and the limited exposure affords no evidence as to the mode of occurrence of the basalt.

No. CXXXVA and B.—**Carlingford**—about one and a half miles south-west of the Railway Station—Hackett's Quarry. Por. 117, Ph. Field of Mars, Co. Cumberland. A. Slightly decomposed Basalt dyke intruding the Wianamatta

Shales. Strike N. 75° E., and width about ten feet. The dip could not be ascertained. The shales in places are highly indurated for a distance of about ten feet from the intrusion. B. Running parallel with A, and separated only by a few feet of shales. About three feet six inches wide, and apparently dipping to the west at about 80°. Although a fair amount of quarrying has been done here, definite particulars concerning these occurrences could not be obtained owing to the quantity of water and *débris* in the excavation.

No. CXLVII.—**Rock Lily**—about half a mile south of Bungan Head. Ph. Narrabeen, Co. Cumberland. Basalt dyke—slightly decomposed—intruding shales and sandstones of the Narrabeen Stage. Strike N. 53° W. Width about four feet, dip south-westerly at 80°. The shales for a distance of about four feet on each side of the igneous rock are slightly indurated; the induration in this instance appears to be fairly uniform. The dyke is exposed in the face of the cliffs forming the coast line, but no evidence of its extension inland could be obtained.

No. CLI.—**Hurstville**—about half a mile south of the Railway Station. Ph. St. George, Co. Cumberland. From the nature of the old workings this is apparently an Olivine-Basalt dyke intruding the Wianamatta Shales. The only evidence at present of an intrusion is a few short shallow trenches extending for about a chain, and the presence of pieces of basalt near the quarry. Apparent strike S. 75° E. I was informed that this place was worked a little for road metal, and that it is some years since operations ceased. There is no indication of a dyke beyond the old workings. A specimen of basalt labelled Hurstville, which has been in the Geological Survey collection for some considerable time, has been microscopically examined, and proved to be entirely different in character to the rock referred to above. Its origin is unknown.

Nos. CXXXVII and CXL.—**Sherbrooke**—Por. 153, Ph. Southend, Co. Cumberland. Olivine-Basalt with large porphyritic crystals of hornblende. Apparently a dyke about thirty feet wide, and striking north-west and south-east. The rock is only exposed for a few feet on the track leading from the saw-mill, and in a small trench about five chains further south-east. Owing to the very limited exposure the mode of occurrence could not be definitely ascertained.

No. CXL.—**Cataract Creek**—Basalt exposed in the Cataract Creek, but its mode of origin could not be ascertained.

No. CXLI.—**Sherbrooke**—Por. 152, Ph. Southend, Co. Cumberland. Basalt is exposed in two small openings on the hillside, and occurs apparently in the form of a sill; about ten feet of solid basalt resting on soft decomposed material, and overlaid by sandstone, which is not appreciably altered. Owing to the very limited exposures the mode of origin could not be definitely determined. Numerous basalt boulders are scattered over the surface in the vicinity.

No. CLV.—**Sherbrooke**—Por. 155, Ph. Southend. Basalt occurring similarly to No. CXLI.

No. CLIV.—**Sherbrooke**—near the Public School. Por. 39, Ph. Southend. Loose pieces of basalt were observed on this block, but there is no evidence as to the mode of occurrence.

No. CXXXVIII.—**Cataract Creek.** Por. 144, Ph. Wonona, Co. Camden. A mass of basalt, probably a dyke, outcrops in the northern bank, and crosses the creek in a south-westerly direction for about one and a half chains. The rock, which extends along the creek for about thirty yards, was not observed on the surface beyond the points mentioned. About five chains further away, apparently along the trend of the intrusion, several small holes have been sunk to a depth of from six to ten feet, and solid basalt obtained. In some instances the sinking has passed through the sound rock into soft decomposed material, similar to that at No. CXLI. This occurrence is directly on the line of strike of No. CXXXVII, and may possibly be a continuation of it.

The examination of the Sherbrooke occurrences has been rather unsatisfactory owing to the limited exposures. Nos. CXXXVII and CXXXVIII are almost on the line of strike of a large dyke struck in the workings at the Bulli Coal-mine, and it is possible that these outcrops represent an extension of that intrusion, and the small sill-like occurrences Nos. CXL, CXLI, and CLV are lateral offshoots from it.

No. CXXXIX.—**Loddon Bridge**—close to the Appin-Bulli Road, about three-quarters of a mile northerly from the Loddon Bridge, and close to the southern boundary of M.P. 2. Ph. Southend, Co. Cumberland. A few small openings on each side of the road have exposed masses of basalt. In the easternmost hole the sinking has passed through the sound rock into decomposed material as at No. CXXXVIII. In the excavations on the west of the road masses of solid basalt are exposed. There is no evidence of a connection of the different occurrences exposed, and in view of the very limited evidence available it is difficult to determine the mode of origin.

B.—*Decomposed Dykes.*

No. LXV.—**Carroll's Hill**—on the Rocky Point Road, about one mile southerly from Kogarah Railway Station. Ph. St. George, Co. Cumberland. Decomposed dyke intrusive into the Hawkesbury Sandstone. It has a slightly sinuous course with a general trend S. 85° E., and dips northerly at about 85°; width five to ten feet. The dyke-rock is now altered into a cream-coloured clay, a quantity of which

has been taken out, leaving a narrow trench about five chains long. The sandstone forming the walls is not appreciably altered. The dyke was not observed beyond the old workings.

No. LXVIII.—**Long Nose Point, Balmain.** Decomposed dyke intrusive into Hawkesbury Sandstone. Strike S. 25° W.; width about one foot six inches; dip nearly vertical. The sandstone along the line of contact does not appear to be altered to any great extent. The igneous rock has weathered away for a short distance, leaving a small fissure to indicate its position. A little white clay can be obtained from the fissure under the steps leading from the Ferry Wharf. Just east of the baths at White Horse Point, Balmain, a fissure, about four feet wide, and bearing S. 35° W., may be observed. This may possibly be a dyke fissure, although the sandstone forming the walls is not altered, nor could any trace of igneous rock be obtained.

No. LXXV.—**Thornleigh**—about three-quarters of a mile N.W. of the Railway Station on Quarry Reserve 119. Ph. South Colah, Co. Cumberland. Dyke—decomposed into white clay—intrusive into the Hawkesbury Sandstone, about three feet six inches wide, and striking S. 85° E., with a northerly dip at 70°. Metamorphism of the adjacent sandstone extends for at least a chain on either side of the intrusion. On the southern side of the dyke, the sandstone, for a distance of about four feet from the contact, is very ferruginous and highly indurated, while on the northern side the alteration is very slight, and in patches throughout the quarry it has assumed a columnar structure, but not within ten feet of the intrusion. The prisms often end abruptly without any apparent reason, and at other times gradually die out. The columns are generally inclined at an angle of from 70° to 80°, and in no instance is there any indication of them radiating from a given centre. In a small patch at the northern end of the quarry the columns are dipping away from the dyke. It is stated that at one time the columnar structure extended right across the quarry face; a distance of about two chains. The absence of columnar structure in the sandstone close to the dyke is a rather noticeable feature, which will be referred to later on (p. 264). The dyke was not observed beyond the quarry.

No. LXXVIA and B.—**Guildford**—about three-quarters of a mile S.S.W. of the Railway Station, on Whittaker's Estate. Por. 99, Ph. St. John, Co. Cumberland.

No. LXXVIA.—This is apparently an offshoot from the main dyke, on the eastern side, and is only exposed where a small hole has been sunk upon it. It is about three feet wide, and dips south-easterly at a high angle. In this instance the igneous rock is decomposed.

No. LXXVIB.—About two chains S.E. of A. A very rotten dyke, striking N. 40° E., and dipping south-easterly at 75°; width about three feet. It does not appear on the surface, and is only exposed where a hole about six feet deep has been sunk upon it. The adjoining shales are not sensibly altered.

No. LXXXIII.—**Burton's Quarry**—about one mile south of Baulkham Hills. Por. 152, Ph. Field of Mars, Co. Cumberland. Decomposed dyke, intrusive into the Hawkesbury Sandstone, striking N. 10° W.; width about three feet. The dip could not be ascertained. In the quarry face on the eastern side of the dyke patches of columnar sandstone may be observed. In a patch adjoining the intrusion the prisms dip to the east at an angle of about 70°, while another small lot about one and a half chains further east are dipping to the north-west at about the same angle. The sandstone between these two occurrences is for the greater part not prismatised, and only slightly indurated. No quarrying has been done on the western side of the dyke, and there are no indications of prismatic structure in that direction. The junction between the Wianamatta Shales and the underlying Hawkesbury Sandstone may be observed close to the quarry. The dyke, which is now decomposed into a soft yellowish clay, is only exposed for about one and a half chains along the strike.

No. LXXXVI-LXXXVIB—**Dural**—Government "White Metal" Quarry—about two miles S.E. of Dural. Ph. South Colah, Co. Cumberland. Three parallel dykes—decomposed—intrusive into the Hawkesbury Standsone. The igneous rock in each case is decomposed into a dirty white clay.

No. LXXXVI.—This is the main dyke in the quarry, and is about four feet wide, striking N. 10° E., with an irregular dip. (Pl. LII.)

No. LXXXVIA.—Situated about one chain easterly from the above, and is indicated by a thin vein, about three inches wide, of white clay running up the quarry face. This intrusion is said to be about six feet wide where quarrying was first started, about one chain from the present face.

No. LXXXVIB.—This dyke is situated about one and a half chains easterly from the main dyke, and is about ten inches wide, with an irregular dip, generally easterly at about 70°. The dykes are only exposed in the quarry face, and here the sandstone is prismatised in places. In close proximity to the main dyke the sandstone is very ferruginous and highly indurated, but not prismatised, and the alteration extends in a lesser degree for about one chain from the dyke. The sandstone is only prismatised in patches throughout the quarry; the prisms often ending abruptly at a bedding plane or joint fissure, and at other times gradually fading away. No prismatic structure is developed within ten feet of the intrusion, while about one chain distant, in the western extremity of the quarry, the structure

is well marked. The prisms in this instance dip north-westerly at 80°. In a small patch on the eastern side of the main dyke the prisms have a vertical dip, while those a little further to the east are inclined to the north at about 80°. The ganger at the quarry stated that the dykes have all narrowed considerably since operations were commenced; the middle dyke in particular decreasing from six feet to a few inches in width within a distance of about one chain.

No. LXXXVII.—**Epping**—about three-quarters of a mile north-east of the Railway Station. Ph. Field of Mars, Co. Cumberland. Decomposed dyke—pure white clay—intrusive in the Hawkesbury Sandstone; about three feet six inches wide, and striking N. 15° E., with a vertical dip. A quantity of the clay has been worked out, leaving a narrow trench about four chains in length, and from ten feet to twenty-five feet deep, with clean walls of sandstone, which is not appreciably altered by the intrusion. Directly on the line of strike, and about three chains further north, quarrying operations have exposed a dyke about eight feet wide, which, although much wider at this point, is probably a continuation of that referred to above. The dyke is not exposed in the vicinity beyond the workings. About ten feet from the western margin of the dyke the sandstone has become columnar, while the rock in closer proximity is only slightly indurated. The columns are five- and six-sided prisms, and vary from two inches to six inches in diameter. In the quarry face, which is about twenty feet long by ten feet high, there is an almost perfect fan-like arrangement of the columns, or, in other words, they are radially disposed, the central columns having a vertical dip. The prismatisation does not appear to extend over a large area. There are several apparently superficial masses of brown iron ore in the vicinity which have probably been deposited from spring water. Some springs are still active, and the deposition of iron oxide may be observed. The ore in some instances is very siliceous, but a quantity of good ironstone flux has been obtained.

No. LXXXIX.—**Quarantine Reserve, North Head**—near The Old Man's Hat. Ph. Manly Cove, Co. Cumberland. The dyke, which is decomposed into a white clay, intrudes the Hawkesbury Sandstone, and strikes N. 45° W., with a south-westerly dip at about 80°. It varies in width from ten feet to fifteen feet. The sandstone forming the walls is indurated for a few feet on each side of the intrusion. It is only exposed on the coast, but a depression cutting across the headland in the direction of the landing stage on the harbour side is probably due to the presence of the dyke, which weathers quicker than the contiguous sandstone. It is also a marked feature in the landscape, forming a break in the cliff face of the headland.

No. XCIX.—**Greendale**—Harbord Estate—about two and a half miles north of Manly. Ph. Manly Cove, Co. Cumberland. A decomposed dyke, intrusive into the Hawkesbury Sandstone. It traces a slightly sinuous course with a general

trend S. 60° E., and dips N. 30° E. at 75°, and is about four feet wide. Along the line of contact the sandstone is converted into a very ferruginous quartzite, and the alteration in a lesser degree extends for about twenty feet on either side of the intrusion. The dyke rock is decomposed into a white clay, which is now being worked. A fair amount of quarrying for "white metal" has been done here, exposing the dyke for a distance of about three chains.

No. XCIXA.—Situated about half a chain northerly from the above, and strikes N. 15° E., with a dip S. 75° E. at 85°, and is about two feet wide. On the eastern side of the intrusion a small band of coarse grit, about three inches wide, may be observed between the dyke-rock and the adjacent sandstone, while on the western side a band of very ferruginous quartzite forms the wall. These dykes do not cross one another, and it is probable that the latter is an offshoot from No. XCIX.

No. CXIX.—**Douglas Park**—in the railway cutting about one mile northerly from the station. Ph. Camden, Co. Camden. Situated about a chain north of No. CXVIII. Very much decomposed rock. Strike N. 35° W.; width about one foot six inches, and dip south-westerly at 80°. The dyke was not traced beyond the cutting.

No. CXXXI.—**Stanwell Park**—just south of the Stanwell Creek outlet. Por. 58, Ph. Southend, Co. Cumberland. Decomposed dyke intrusive into shales and sandstones of the Narrabeen Stage, and striking S. 70° W.; width about four feet, and dip vertical. The dyke-rock has weathered away, leaving a fissure about a chain long, but portion of the sound rock may be observed outcropping just below high-water mark. The igneous rock decomposes into a white clay. About half a chain north of the above a small dyke varying from two to eighteen inches in width can be seen in the cliff face, striking S. 55° W., and dipping south-easterly at 82°. This is apparently an offshoot from the larger mass, but it was not possible to trace it any distance. The rock in this instance is much decomposed.

No. CXXXVI.—**Appin**—Ph. Wedderburn, Co. Cumberland, about three miles S.S.W. of Appin. Decomposed dyke intrusive into the Hawkesbury Sandstone, striking S. 55° E., with an irregular dip; width from five to nine feet. The sandstone for about half a chain on each side of the dyke is more or less indurated. On the northern side of the quarry a small intrusive sheet or sill may be observed striking off along a bedding plane of the sandstone. It varies from a few inches to two feet in thickness, and is about twenty feet long. The dyke-rock is decomposed into a pure white clay, and although it is not exposed on the surface beyond the quarry, quantities of quartzite outcropping at intervals along the line of strike are a very good indication of its presence. In a creek about a mile south-easterly from the quarry a clay dyke, probably a continuation of the above, is exposed.

No. CXLIX.—**Hurstville**—about three-quarters of a mile S.E. of the Railway Station—Blake's "White Metal" Quarry. Ph. St. George, Co. Cumberland. Dyke intrusive in the Hawkesbury Sandstone. It traces a sinuous course, trending S. 85° E., with a southerly dip at 85°, and is about five feet wide. The dyke-rock is decomposed, forming a cream-coloured clay, which hardens on exposure. Metamorphism of the sandstone, in a more or lesser degree, extends for about half a chain on each side of the intrusion; the sandstone in places being converted into a kind of quartzite, and generally bleached. For about ten feet on either side of the dyke the sandstone has generally assumed a well-marked prismatic structure; the prisms varying considerably in size, up to eight inches in diameter, and dipping across the bedding planes at from 45° to 80°. The following dips were obtained within a distance of one chain along the line on the southern side:—West at 65°, S. 80° W. at 75°, and S. 10° W. at 45°. Quarrying operations have exposed the dyke for a distance of about eight chains, but it was not observed beyond this. Unfortunately most of the prismatic portion, which extends the whole length of the workings, has been destroyed during the process of excavation.

Dyke CL.—**Kensington**—about half a mile south of the Kensington Racecourse, and close to the Bunnerong Road. Ph. Alexandria, Co. Cumberland. Dyke intrusive in the Hawkesbury Sandstone. The dyke-rock is decomposed, forming a pure white clay, which has been worked at intervals for a distance of about five chains along the line of strike. It is from two to four feet wide, and traces a slightly sinuous course, with a general trend S. 75° E., and a vertical dip. The sandstone in close proximity to the intrusion is generally more or less indurated, and in places very ferruginous. Beyond the workings the dyke is concealed by wind-blown sand.

The Water and Sewerage Board have kindly supplied the Geological Branch with information concerning two dyke-exposures, and the following is an extract from their letter:—"Two and a half miles from the inlet of the Nepean (Nepean River to Cataract River) Tunnel, practically under Allen's Creek, a decomposed dyke, about four feet wide, and running north and south, has been pierced, roughly at a depth of one hundred and fifty feet below the bed of Allen's Creek at that point. A similar dyke is visible on the new road cutting on the Appin-Wilton Road, just east of Allen's Creek Bridge, and from its position is believed to be a continuation of that struck in the tunnel."

C.—*The Volcanic Necks.*

The necks recorded in the Sydney District number sixteen, and are widely distributed. Several have been known for many years, especially Prospect and Pennant Hills, which attracted attention in the early days of settlement. Perhaps, with the possible exception of those close to the Nepean River, the necks, as distributed, are not suggestive of arrangement along great lines of weakness in the earth's

crust. Unfortunately the very limited exposure of the surrounding rocks affords no opportunity of determining a fault. At Bargo, where the rocks are a little bared on either side of the neck, they are seen to consist of thick bedded Hawkesbury Sandstone with no distinctive features. As far as the Writer is aware, the necks recorded in this paper have not been previously described.

It has not been possible to define the exact boundary of any of these necks; with one exception they appear as eminences, generally as smooth rounded grassy hills, the present configuration being due to denudation of the intruded strata. Although the actual margin of the vents is not exposed, it is clear that, with the exception of Hornsby, they are in no instance extensive, Erskine Park, the largest, being only about fifteen chains in length, by about ten chains in breadth.

Generally the necks are composed entirely of fragmentary material, apparently mainly derived from the rocks now exposed on the surface, and, with the exception of Hornsby, unless Glenlee be included, no basalt was actually observed in them. In nearly every instance calcite is largely developed as a secondary mineral in the agglomerates. There is a marked resemblance between the volcanic accumulations in the Erskine Park, Minchinbury, and Menangle necks, but in that of Bargo, the large amount of quartzite present in the agglomerate, together with a rather coarser sandy matrix, renders the filling distinct. Although basalt has been observed in close proximity to three of the agglomerate necks, there is an apparent absence of a central plug. Possibly denudation has not proceeded far enough to expose the column, or these small vents may never have been active lava vocanoes. They may represent mere blow-holes where the funnels were filled with *débris* of the rocks pierced, as indicated by the large proportion of sandstone and shale present in the filling.

At Menangle the periphery of the neck is exposed for a few feet, and here the division between the agglomerate and shales is quite sharp; the sedimentary rocks showing no signs of shattering or tilting. Perhaps these vents are analogous with the laboratory experiments which have shown that gases under great pressure in an iron casing drill straight, smooth holes at points of weakness. Like the dykes, the necks are younger than Triassic, since sandstones and shales, probably belonging to that period, constitute a large proportion of the volcanic accumulations, but whether they belong to the same period of volcanic activity as the former has yet to be proved.

The domed outlines of the necks described are strongly contrasted at Hornsby, where one occurs as a huge dumb-bell shaped depression, fully three hundred feet deep, with precipitous walls of Hawkesbury Sandstone. It measures about one mile in length, by about a quarter of a mile in greatest breadth. The neck filling

in this instance consists of a dense blue volcanic breccia with occasional blocks of basalt, and is distinct from the others described. This is the only instance where basalt *in situ* has been observed in the actual chimney associated with volcanic breccia. In its mode of occurrence the Hornsby neck resembles those at the Basin on the Nepean River, at Springwood, and Euroka Creek, as described by Mr. C. S. Wilkinson, Professor David, and Mr. E. F. Pittman.

The rude spheroidal structure exhibited by the agglomerate where exposed to the weather, in several instances, is a noticeable feature.

Bargo.—The Sugar Loaf, about four miles S.E. of Thirlmere. Por. 101, Ph. Bargo, Co. Camden. The neck forms a prominent feature standing out as a bold isolated hill in the centre of a small valley. It is apparently roughly circular in ground-plan, with a diameter of about seven chains, and rises to a height of about sixty feet above the surrounding Hawkesbury Sandstone. The actual junction of the neck with the rock through which it rises is obscured by herbage, and the material filling up the vent is only exposed where quarrying operations have been carried on. The material of the neck consists, where exposed, of a coarse volcanic agglomerate, with blocks varying in size up to three feet. The most prominent of these, especially on the western slope, are pieces of altered sandstone—quartzite—but fragments of shale, and other rocks which were not identified, are also included. The matrix is dirty green in colour, and weathers with a brownish surface on which the included fragments show out conspicuously. The inclusions of sedimentary rock are generally highly altered. Calcite occurs as amygdales through the rock, and as films along joint planes. As a result of old quarrying operations, a large fissure with walls of indurated shale now exists on the eastern side of the hill. Work has been carried on at this spot, probably on account of the hardness of the rock, but beyond the presence of shale there is no evidence of a change, the bottom of the fissure being covered with agglomerate boulders. Although no basalt is visible in the vicinity these workings may possibly indicate the position of an intrusion of that rock. The beds of sandstone exposed in the creek a few chains west of the neck are apparently undisturbed, and the rock is unaltered. The junction line of the base of the Wianamatta Shales with the top of the underlying Hawkesbury Sandstone is just about the summit of the hill forming the neck, as a comparison of the levels in the neighbourhood proves. The Rev. W. B. Clarke refers to this occurrence as follows :—" Again, at the Sugar Loaf Hill, near the Bargo River, the boss of trap which forms that conical summit amidst the bush is yet partially covered by transmuted sandstone *in situ*, the relics of the masses that have been swept away. There, all the changes are easily traceable from unaltered to highly vitrified compact beds ; the basalt itself having in all its features, especially the calcareous portions, the closest resemblance to the Pennant Hills rock."*

* Trans. Phil. Soc. N. S. Wales for 1862-65, p. 294.

Menangle.—About half a mile west of Mount Gilead. Por. 35, Ph. Menangle, Co. Cumberland. Quarrying operations on the summit of a hill about a hundred feet above the Menangle Creek have exposed a mass of hard volcanic breccia surrounded by shales and sandstones of the Wianamatta Stage. The exact shape of the neck could not be determined as the periphery is only exposed for a few feet at the entrance to the quarry, but it is apparently about ten chains in length from north to south, and about five chains in breadth. The material of the neck varies from coarse agglomerate to fine tuff. The agglomerate is greenish-grey in colour, and is composed mainly of boulders and fragments of fine-grained calcareous sandstone, shale, and quartzite, embedded in a calcareous tuffaceous matrix. It is stated that blocks of granite are occasionally met with. The included blocks range in size up to four or five feet square, and are in some instances considerably indurated. Secondary calcite has been largely developed through the rock, and especially along the joint-planes. The tuff in places is a hard, dense, black rock, which, at a casual glance, may be mistaken for basalt. An isolated patch of shales may be observed in the body of the neck; it is wedge-shaped, being about ten feet wide at the top tapering away to about four feet at the bottom, and about ten feet high. These shales are not metamorphosed to any appreciable extent, being only blackened and very slightly indurated. The agglomerate exhibits a rudely spheroidal structure. No basalt was observed in any portion of the neck, but on the eastern side, apparently outside its margin, loose boulders of that rock are exposed in two places, and these may have been shed from a dyke close by, or may possibly be portions of the neck-material. A small portion of the margin of the neck is exposed by a cut in the hill-side, showing a sharp and well-defined junction line with the contiguous shales, which are apparently neither disturbed nor sensibly altered.

I am indebted to Mr. C. O. G. Larcombe, of the Geological Survey Branch, for calling my attention to this interesting occurrence.

Glenlee Quarry—near Mount Anna, and about three miles W.S.W. of Campbelltown. Ph. Narellan, Co. Cumberland. On the summit of a low hill quarrying operations were carried on, and have now left a circular excavation about twenty feet in diameter by about fifteen feet deep, to indicate the position of an igneous intrusion, probably a volcanic plug. The rock which is intrusive into the Wianamatta Shales of the Triassic Series is a hard Olivine-Dolerite, but very little of it is now exposed *in situ* owing to a quantity of *débris* in the excavation. Metamorphism of the shale extends for some distance from the igneous mass, in some places intense induration being exhibited. Some of the rock specimens obtained in the vicinity, although much decomposed, appear to be fragmentary, and may possibly be of volcanic origin, but no confirmatory evidence could be obtained.

There is no record of a dyke in the vicinity. Work in the quarry has been suspended for some time past, but a quantity of the dolerite has been left scattered about the surface, and from the nature of the old workings, and after consideration of the facts obtained, it was decided to class this occurrence among the necks.

Minchinbury—about two miles south of Rooty Hill Railway Station. Por. 15, Ph. Melville, Co. Cumberland. The Minchinbury Trig. Station is on an elevated portion of the neck. At the western extremity of a short range of hills quarrying operations have exposed a mass of hard volcanic agglomerate and tuff. (Pl. LIV.) Although the margin of the neck is concealed by herbage, it is apparently roughly circular in shape, with a diameter of about ten chains. The agglomerate is coarse, and consists mainly of blocks and fragments of sandstone and shale embedded in a compact greenish-grey matrix; a number of quartz pebbles about the size of a hen's egg are also included. Masses of hard black tuff, very similar to that in the Menangle neck, are exposed in places. A great amount of calcite occurs in patches through the rock, and as films along the joint planes. The included blocks of sedimentary rock are generally not highly indurated, and vary considerably in size. The rock weathers into spheroidal boulders with a brownish surface, on which the included fragments show out conspicuously. In places the agglomerate has the appearance of being rudely bedded, but this, no doubt, is only due to jointing. The enclosing strata are beds of shale and sandstone of the Wianamatta Stage, and in no instance is the actual contact with the agglomerate exposed, nor is there any evidence of the beds being disturbed or altered in any way. No basalt was observed in the immediate vicinity of the neck, but about half a mile to the south-east a basaltic dyke has been opened out for a considerable distance in a north-easterly direction, but there is no evidence of a connection between this dyke and the neck.

Erskine Park—about three miles S.S.E. of St. Mary's Railway Station. Por. 41, Ph. Melville, Co. Cumberland. The Erskine Trig. Station is situated within the area of the neck. The neck, which is very similar in character and composition to the Menangle neck, forms a conspicuous feature in the landscape, projecting above the surrounding Wianamatta Shales. (Pl. LIVA.) It is about fifteen chains in length by seven in breadth. There are four distinct low eminences running in a north-easterly direction from the Trig. Station, but whether they mark the presence of separate vents, or are only the result of denudation, the evidence available does not enable me to state. The shape of the neck can only be assumed from the contour of the hill, as the margin is concealed by the growth of herbage. The material filling up the vent in the visible portions is a coarse agglomerate composed mainly of blocks and fragments of calcareous sandstone, shale, and quartzite, embedded in a compact greenish-grey matrix. A large amount of secondary carbonate of lime has developed along the joint planes and through the rock. The included blocks vary in size, and in some instances are highly indurated, but

generally the alteration is very slight, and at the southern end of the area a good face of agglomerate, exhibiting spheroidal structure, due to weathering, is exposed. No basalt was observed in any visible portion of the neck, but about a quarter of a mile to the south a number of basalt and agglomerate boulders are scattered about in the bed of a small creek; there is, however, no exposure of the basalt *in situ*. A little quarrying has been done, and has exposed the agglomerate in several places round the hill.

Hornsby.—The Old Man's Valley—about half a mile W.N.W. of the Railway Station. Por. 75, Pb. South Colah, Co. Cumberland.

The neck occurs as a depression almost surrounded by precipitous walls of Hawkesbury Sandstone. It is roughly dumb-bell shaped in ground plan, measuring about one and a quarter miles in length, by about a quarter of a mile in greatest breadth. The steep sides of the valley rise fully three hundred feet from the low ground to the general level of the enclosing sedimentary rock. The volcanic accumulation in the visible portion of the neck consists of a dense blue breccia, with occasional blocks of basalt of varying sizes. The breccia is well exposed along the creek running through the valley, and blocks of basalt embedded in the breccia may be observed in the bed of the watercourse about the centre of the neck. The junction of the breccia with the sedimentary rock is obscured by talus and herbage, but, from the large number of altered sandstone—quartzite—boulders on the slopes, especially about the western portion of the neck, it is evident that the Hawkesbury Sandstone has been intruded, and the neck is therefore younger than that formation. The growth of timber within the area of the neck stands in strong contrast to that on the barren sandstone country adjoining. Advantage has been taken of the superior quality of the soil to cultivate a portion of the valley.

This interesting occurrence was first examined and mapped by the Rev. J. M. Curran, and C. A. Sussmilch.

GENERAL OBSERVATIONS.

Distribution of the Dykes.—The known occurrences of intrusive dykes are apparently unequally distributed over the area. Along the coast between Port Jackson and Botany Bay they are concentrated in comparatively small compass, and over the remaining part of the country they are generally scattered, and in numerous cases practically isolated. Such a wide difference may be explainable on the assumption that a centre of great volcanic energy existed near the present coast east of Sydney, and that the sparse distribution of the remainder throughout the larger area inland is probably more apparent than real, owing to the obscuring

influence of the fertile Wianamatta Shales and the absence of sections such as facilitate discovery in the coastal area.

Strike of Dykes.—Some dykes maintain fairly true courses for considerable distances, but the majority, even where only exposed for a few chains, are inclined to sinuosity. The prevailing strikes of those on the coast near Sydney are from east and west to north-west and south-east. The dykes further inland to the east of Burwood, with few exceptions, have a north-easterly trend. One notable exception is the large dyke at Luddenham (No. CIX), which strikes north-westerly. It would therefore appear as if two distinct sets of fissures were originally formed which determined the course of these dykes. In no instance, however, has an intersection of dykes of different groups been observed, nor is there any evidence as to their relative age. Mr. G. A. Waterhouse, B.Sc., first noticed a general convergence of a number of the coastal dykes, a feature independently observed by Mr. E. M. Metcalf, of the Department of Mines and Agriculture, who, after plotting the lines of strike of a number of them, found that the centre of convergence would be about twenty-three miles to the east of Botany Heads. The occurrence of a number of dykes along definite radial lines would thus indicate a focus of disruptive energy in the direction mentioned.

Surface indications.—With a few exceptions the dyke outcrops are ill-defined. It is evident from the disconnected quarries along a number of them that only the outcrop has been attacked. An interesting feature in the mode of occurrence is the absence of a continuous solid outcrop along the line of strike—the dyke at surface assuming the form of a series of isolated lenses, probably due to the failure of the igneous material to rise to the present land surfaces and the abrupt lateral changes as described in Nos. LXXIX and CVII. The overseer at Guildford quarry drew attention to narrow fissures in the Wianamatta Shales, apparently following the trend of the dyke where it has not reached the surface, and stated that these are considered indicative of its presence at a shallow depth. The fissures are from one to two inches wide, and extend for a distance, sometimes exceeding one hundred yards, and have since been observed forming connecting links, as it were, between the isolated outcrops of a dyke in different localities within the Wianamatta Shale area. In several instances where holes have been sunk along the line of fracture the dyke has been struck at from four to ten feet below the surface. The fissuring of the superficial shales along the strike of the dyke is explicable on the assumption that the latter suffers practically no contraction under the influence of the weather, while the more absorbent shales expand and contract during alternating wet and dry periods. The igneous rock, therefore, forms a line of parting, from both sides of which the unstable shales contract in dry weather, thus giving rise to the fissure. Thus it is evident that absence of continuity of outcrop must not be taken as proof of the discontinuity underground.

Similar fissures have been observed in many places over the Wianamatta Shale area, but generally they have a very sinuous course.

Decomposition.—A very distinctive feature brought out during the observations is the fact that the dyke-rocks, where intrusive in the Hawkesbury Sandstone area, are usually much decomposed, whereas these traversing the Wianamatta Shale country are comparatively fresh, even at the surface. In the shale country the dykes are usually worked for blue metal, whilst those in the sandstone are generally decomposed into clay of a creamy colour which in several localities is worked for pottery and other purposes. There can be little doubt that the changes are largely due to the unequal resistance to weathering of the two enclosing rocks, the igneous rock succumbing more readily than the sandstone, whilst the shales yield to denuding agencies more rapidly than decomposition proceeds in the basaltic rocks.

In places along the coast dykes have weathered away, leaving fissures about a chain long with walls of indurated sandstone. Sound basalt is recorded in connection with but a few of the intrusions in the Hawkesbury Sandstone round Sydney, but in the case of several dykes at Seal Bay it is seen that though decomposed at the surface, the dyke rock is sound at a comparatively shallow depth.

Age of the Dykes.—The dykes described herein are younger than Triassic, since they have intruded the Wianamatta Shales assigned to that period. How much younger they may be is difficult to decide, but it is not improbable that they represent another phase of that period of volcanic activity, the remnants of which now exist in the Hawkesbury Series further west, in the form of lava sheets and necks of late Tertiary age.

Metamorphism.—The physical effects of the dyke contact on the intruded strata alone are noted, as it is not proposed to enter into the complex subject of contact metamorphism. The amount of alteration varies considerably, being sometimes very marked along the walls of an intrusion—as at Rookwood (No. LXXIV), where the shales are bleached and highly indurated for about three feet from the contact, and about a chain along the line of strike—whilst at other points the alteration is hardly appreciable. Such intense alteration as that referred to was not observed in connection with the larger dykes.

On the Harbord Estate (No. XCIX) alteration in varying intensity extends for about a chain from the dyke; along the contact the sandstone is vitrified and very ferruginous. At Kogarah (No. LXV), on the other hand, the sandstone is only slightly altered for a few feet from the intrusion. Such variations in the amount of alteration is probably determined, to a large extent, by the chemical composition and structure of the rocks affected.

Sir A. Geikie, in referring to the differences observed in the extent of metamorphism superinduced by adjacent dykes in the west of Scotland, says :—*

"Such variations have not probably arisen from differences in the temperature of the original molten rock. Perhaps they are rather to be assigned to the length of time occupied by the ascent of the lava in the fissure. If, for instance, the fissure opened to the surface and discharged lava there, the rocks of its walls would be exposed to a continuous stream of molten rock as long as the outflow lasted. They would thus have their temperature more highly raised, and maintained at such an elevation for a longer time than where the magma, at once arrested within the fissure, immediately proceeded to cool and consolidate there."

PRISMATISATION.

Columnar structure of the sandstone is a noticeable feature in the vicinity of some dykes. In only one instance has prismatic structure in the sandstone been observed by the writer without visible trace of igneous rock in the vicinity, although other instances are known, Mr. G. W. Card states that the prismatic structure at Lane Cove (Pl. LI) is not associated with intrusive rock.

The prisms are generally arranged nearly at right angles to the bedding planes, and are usually much lighter-coloured than the unaltered rock. In some instances the sandstone forming the prisms is converted into quartzite; in other places the alteration is so slight that quarrying operations ceased, as the stone "white metal" is too soft for road-making. Both these phases of metamorphism are represented in the Dural quarry (No. LXXXVI).

Perhaps the most interesting feature in connection with the prismatic structure is its absence in many cases at the actual contact of the sandstone with the dyke. At Epping (No. LXXXVII) it does not approach nearer than ten feet to the intrusion. At Thornleigh (No. LXXV) and Dural (No. LXXXVI) the intervening sandstone for five to ten feet on either side of the dyke is only indurated. (Pl. LII.) In places where prismatic structure occurs in limited patches throughout a quarry, small isolated groups have been observed fully a chain from the dyke. It sometimes either ends abruptly, without any apparent reason, at a bedding plane or joint fissure, or gradually dies out. At Epping the prisms have a perfect fan-shaped arrangement, or, in other words, are radially disposed with vertical central columns. This structure has been reported as occurring in several other localities round Sydney—Bondi, Five Dock, Lane Cove (Pl. LI.)

It appears evident from these facts that mere contact with the molten material has not produced the changes. It is probable that heated vapours coming from the molten magma, combined with the varying composition and texture of the rocks affected, were the principal cause of the metamorphism effected.

* Ancient Volcanoes of Great Britain, II, p. 165.

The Rev. W. B. Clarke expressed the opinion that :—

" . . . . this kind of structure is not generally observable in the purest sandstone, and the prismatic action is therefore due, perhaps, to a molecular alteration as well as to the element itself which holds the siliceous particles together having been affected by heat."

In writing on Metamorphism in and around volcanic vents, Sir A. Geikie says :—*

" Mere heat will indurate rocks, baking sandstone, for instance, into quartzite and shales into porcellanite. But there will almost invariably be causes of alteration other than mere high temperature. Water-vapour, for instance, has probably always been one of the most abundant and powerful of them."

At Blakehurst (No. CXLIX), and near Baulkham Hills (No. LXXXIII), the prisms occur in contact with the dyke, and are generally inclined at from 45° to 75°, but in no instance are direction and inclination constant. In the former case a number of prisms dip towards the dyke, whilst in the latter the inclination is usually the reverse, as regards the intrusion. Seldom have they been observed arranged at right angles to the sides of the dyke, but generally occur, apparently, entirely independent of it. In view of these facts it is difficult to attribute the structure, even in these cases, to direct contact with the intrusive rock.

At *French's Forest*, about four miles N.W. of Manly, and about one mile W.N.W. of the Manly Trig Station, quarrying operations are carried on in slightly indurated and prismatised Hawkesbury Sandstone. The prismatisation is as a rule rather imperfect, and occurs in patches across the quarry face—which is about three chains in width, and fifteen feet high—and does not appear to extend for any great distance in from the present workings. The prisms, which are generally fairly large, some measuring a foot or more in diameter, are five- and six-sided, and are dipping S. 20° W. at about 70°. There is no visible trace of any igneous rock in the vicinity, and this is the only instance which has come under my notice where the igneous rock is not exposed in the near vicinity of the prismatic sandstone, although a similar case is known at the head of the Lane Cove River, and another is reported on the North Head, south of Manly. At Blakehurst when the quarry was opened no trace of igneous rock was visible, but in the course of working a decomposed dyke was exposed, and it is possible that an igneous intrusion may yet be met with in the French's Forest quarry.

I am indebted to Mr. G. W. Card for the views of the Lane Cove prismatised sandstone reproduced on Pl. LI.

Referring to columnar sandstone in the Isle of Bute, D. C. Glen suggested steam

* Ancient Volcanoes of Great Britain, I, p. 71.

as the cause of the prismatisation, in the absence of igneous rock.* For comparison the following description of the mode of occurrence of Bute prismatic sandstone by Mr. W. Gunn† is interesting :—

" The tract is about twenty yards wide on the shore at high-water mark, and it appears to run in a north-east direction parallel to the course of many of the intrusive dykes along this shore, for the columnar structure may be observed in the old sea-cliff seventy yards south-west of the shore line at this point. The columns are fairly regular five- and six-sided prisms, some of them as much as seven inches in diameter. The dip of the sandstone and conglomerate is to the south-south-west at 30°, and the columns are arranged nearly at right angles to the planes of bedding, so that they incline steeply to the north-north-east. The pebbly rocks or conglomerates appear to be as much altered as the finer sandstone ; both are much hardened, in fact converted into a kind of quartzite, and they are much lighter in colour than the unaltered rock. It seems probable that this structure is due to a concealed dyke—one which does not reach the present surface—running in a north-east direction."

This is the only instance known to the Writer at all analogous to the Sydney occurrences.§ Columnar sandstone due to direct contact with a sill of igneous rock, and with parallel prisms, is well known.

Perhaps the best example of columnar structure in the Sydney District is that exposed in the cliffs at Bondi, on the coast, which has been described by the Rev. W. B. Clarke, Prof. David, and the Rev. J. Milne-Curran. Several other occurrences have been noted and described by the first mentioned in his paper on the " Transmutation of Rock," and a list of localities has been given by J. M. Curran in his Geology of Sydney, p. 261. The localities in the area under discussion, at which prismatic sandstone is known to occur, are—Bondi, La Perouse, Five Dock, Pyrmont, Dural, Epping, Thornleigh, French's Forest, near Baulkham Hills, head of Lane Cove River, and near Hurstville.

The following description of columnar structure in loose sand by G. and J. M. A. Skeldon‡ is interesting to note :—

" A bed of fine sand, so incoherent as to run almost like water when touched, showed in one face a beautiful columnar structure. Perpendicular columns of sand rising one tier above another, clear, sharp, and distinct ; some broken off at the middle, others nearly touching the overhanging cap of clay."

---

* Trans. Geol. Soc. Glasgow, 1875, V, p. 154.

† Geol. North Arran, &c., Mem. Geol. Survey Scotland, 1903, p. 33.

‡ Newly Exposed Geologic Features within the old "8,000-acre Grant," by G. and J. M. A. Skeldon, New York, 1903.

§ Writing of the relation between volcanic pipes and the enclosing sandstone at Sutherland, Cape Colony, Messrs. A. W. Rogers and A. L. Du Toit say :—"The thin sandstones and shales are distinctly hardened near the pipe, and in places have a well-developed columnar structure ; the columns range from 12–14 inches in diameter, with their axes directed away from the pipe, but in some cases they are curiously curved and arranged in radiating groups."—*Ann. Rept. Geol. Comm. C. Good Hope for* 1903 [1904], p. 46.

PETROGRAPHICAL NOTES.

(By GEORGE W. CARD.)

Bankstown. (No. LXXV.)

Museum specimen 10915.

Altered Doleritic Basalt.

An aphanitic rock, breaking with an even fracture; a lens is necessary for the identification of the constituents. It is uniformly calcareous.

Under the microscope the rock is seen to be micro-porphyritic in texture, due to the presence of small phenocrysts of felspar. It consists essentially of felspar, calcite, and magnetite. No ferro-magnesian mineral can now be recognized, but the calcite no doubt represents the destruction of such. The felspar is fresh, and shows a high angle of extinction on 100.

Guildford. (No. LXXVI.)

Rock specimen 4748.

Amygdaloidal Dolerite ('Diabase').

A highly altered, very calcareous rock.

Under the microscope it is seen to consist of abundant calcite, serpentinous (or chloritic) areas, iron ores, augite, and felspar. The serpentinous areas are radially fibrous, and pale green in colour; they are sometimes surrounded by calcite. Iron ore is abundant—comprising magnetite, and ilmenite with leucoxene. The augite is brown and granular. The felspar is labradorite, forming laths and plates.

Guildford Basalt. (No. LXXVI C.)

Rock specimen 4854.

Olivine-Basalt.

A very compact rock showing what appears to be an inclusion of a similar but coarser variety.

Under the microscope it shows phenocrysts of olivine in a groundmass of felspar microlites, augite granules, and magnetite dust.

The olivine is fresh and perfectly automorphic.

Wentworthville. (No. LXXVII.)

Rock specimen 5258.

Olivine-Basalt.

A black, jointed rock.

Under the microscope it is seen to be holocrystalline and micro-porphyritic, with small phenocrysts of olivine, and still smaller ones of augite and felspar in a granular groundmass of augite, felspar, and magnetite.

Olivine is abundant and highly serpentinized. For the most part it is corroded and xenomorphic.

Felspar occurs as fluidally-disposed laths.

Smithfield Dyke. (No. LXXVIII.)
Rock specimen 5257.
Olivine-Basalt.

Olivine is readily visible, and the rock tends to become doleritic in texture.

Under the microscope the olivine is seen as corroded, more or less serpentinized, phenocrysts in a groundmass of augite, lath-shaped felspar and magnetite.

Minchinbury Dyke. (No. LXXIX.)
Rock specimen 5271.
Analcite-bearing Olivine-Basalt.

A dense black rock in which green olivine is readily discernible.

Under the microscope phenocrysts of more or less serpentinized olivine lie in a groundmass of augite, lath-shaped felspar, magnetite, and analcite.

Olivine is at times perfectly automorphic ; it is far advanced in serpentinization.

Analcite occurs interstitially, both as colourless material traversed by black rods, and as a dusky-brown alteration product.

This rock presents close analogy to that from the Luddenham dyke.

Baulkham Hills. (No. LXXXII.)
Rock specimen 5307.
Olivine-Basalt.

Aphanitic and non-porphyritic in texture, with occasional small amygdales. Fracture uneven, colour blackish-grey.

Microscopical characters.—Texture, micro-porphyritic, phenocrysts of olivine being present; holocrystalline.

Olivine occurs as xenomorphic phenocrysts. Serpentinization is very considerable, the replacement being sometimes complete.

Felspar occurs as laths showing distinct albite lamellation, and also as a general base.

Augite forms granules and little prisms of a violet colour.

Magnetite is very abundant in uniformly-distributed little crystals.

Rooty Hill. (No. CIV.)
Rock specimen 5267.
Olivine-Dolerite.

The constituents can be readily distinguished with a lens.

Under the microscope the grain-size of all the constituent minerals is seen to vary by insensible gradations. It consists of olivine, augite, felspar, magnetite, and perhaps analcite.

Olivine is not automorphic. For the most part it is serpentinized, but an unaltered kernel is occasionally seen.

Augite is also not automorphic. Purple in colour, but not appreciably pleochroic. It may occur in aggregations.

Felspar appears to be a plagioclase at least as basic as labradorite.

Analcite. An isotropic substance, apparently secondary, is regarded as analcite.

St. Marys. (No. CV.)
Rock specimen 5268.
Altered Dolerite.

A dark green, highly calcareous rock, the constituents of which can be readily discerned with a lens.

Under the microscope laths and plates of fairly fresh felspar are seen, but the other constituents are much altered.

St. Marys. (No. CVII.)
Rock specimen 5270.
Olivine-Dolerite.

A greenish-black rock, the constituents of which are readily discernible.

Under the microscope, phenocrysts of olivine, augite and some felspar are seen embedded in a holocrystalline groundmass of the same minerals with magnetite and analcite.

Olivine is corroded and much shattered. Serpentinization has occasionally produced pseudomorphs, but is for the most part incipient only.

Augite is somewhat purple and slightly pleochroic. It may occur in clusters, and can also be seen wrapping round olivine.

Felspar occurs in slender lath-shaped crystals showing a high extinction angle.

Analcite appears to be secondary as amygdales—at least in part, in this respect resembling the altered dolerite of Prospect.

Magnetite is generally disseminated in small crystals.

Luddenham Dyke. (No. CIX.)
Rock specimens 5240–4.
Analcite-bearing Olivine-Basalt.

A compact rock showing an abundance of fresh olivine.

Under the microscope it shows phenocrysts of olivine and purple augite in a granular groundmass of augite, felspar (in laths), magnetite, and analcite.

The olivine is much cracked. It shows incipient serpentinization, and occasionally a complete pseudomorph.

The augite is automorphic, purple and pleochroic. It is sometimes parti-coloured—grass-green and purple. The phenocrysts may occur in aggregations.

The felspar is on the whole inconspicuous.

Apatite occurs in long needles.

Analcite is abundant. It is colourless and isotropic when unaltered, but may be represented by certain dusky yellowish products. It is traversed by radiating or anastomosing black rods.

A little biotite is present.

An analysis has been made by Mr. J. C. H. Mingaye, and will be found in Part III of these Records, page 230.

Minto. (No. CX.)

Rock specimen 4928.

Olivine-Basalt.

A porphyritic rock containing abundant amygdales of calcite.

Under the microscope phenocrysts of colourless monoclinic pyroxene and serpentine (with residual olivine) are seen embedded in a holocrystalline groundmass of granular light brown pyroxene, felspar laths, and abundant iron ore. Chloritic products are present in sufficient quantity to give rise to a general green colouration. The felspar rods are somewhat fluidal.

Cataract Creek. (No. CXXXVIII.)

Rock specimen 6026.

Olivine-Basalt.

A compact rock with small masses of olivine and some calcite. Blackish-grey in colour.

Under the microscope much irregular phenocrystalline olivine, showing incipient serpentinization is seen. The groundmass is very fine-grained, showing minute plagioclase laths and very minute grains of augite and magnetite. No phenocrystalline augite are present. Some irregular areas are occupied by isotropic colourless matter, or by serpentine and calcite (? amygdaloidal).

Menangle.

Rock specimen 5201.

Olivine-Basalt.

Aphanitic in texture, not distinctly porphyritic. Colour greenish-black, fracture uneven. Quartz occurs, but is no doubt allogenic. Masses of black augite and pyrite are also present. The rock weathers into rounded masses of a brown colour.

Microscopical characters.—Small phenocrysts of olivine, serpentine, and augite occasion a strongly micro-porphyritic texture. The rock has been much altered.

Olivine occurs as xenomorphs principally, but automorphs occur occasionally. Serpentinization is usually complete.

Augite is at times automorphic. Pale brown in colour. Alteration has affected it greatly, the magma having sometimes eaten it through and through. The marginal zone may be fairly fresh and the centre altered, or the converse may be the case. Spots of calcite are sometimes present.

Magnetite forms masses associated with serpentine, and also as a general pigment.

The Groundmass is very dense with pigment spots. Minute felspar microlites and viridite are scattered through it.

Glenlee.

Rock specimen 5247.

Olivine-Dolerite ('Diabase').

This rock is slightly amygdaloidal. The components are readily visible under a lens.

Under the microscope it is seen to be holocrystalline and non-porphyritic, and to consist of lath-shaped felspars, augite, olivine, magnetite, and biotite.

Felspar appears to be the dominating constituent. It is fresh, and to some extent automorphic. Extinction angles up to 30° were obtained on 100, indicating labradorite.

Augite is purple in colour and pleochroic. It is somewhat automorphic.

Olivine is both fresh and serpentinized, occurring in irregular grains or as more or less misshapen crystals.

Magnetite occurs in generally-distributed crystals.

Biotite forms numerous wisps, brown in colour, but not strongly pleochroic. It also occurs as splashes, more particularly in the felspar. The frequency with which it occurs in irregularly-polarizing areas suggests a possible derivation from the extreme alteration of fragments of shale caught up by the magma.

APPENDIX I.

LITERATURE

Relating to the Igneous Intrusions in the vicinity of Sydney. Information relating to prismatisation of Sandstone will be found in references marked *.

1. LESSON, P.—Voyage Autour du Monde. Duperrey. Paris, 1826. Vol. I (1st Part).
   [Reference to Prospect Hill, page 388.]
2. CUNNINGHAM, P.—Two Years in New South Wales. (8vo. London, 1827.)
   [Brief reference to the fertility of certain areas of decomposed 'whin, pp. 340-341.']
3. MITCHELL, T. L.—Three Expeditions into the Interior of Eastern Australia. 1838. Vol. 1.
   [Brief reference to Norton's Basin, on the Nepean River, now known to be a volcanic neck, p. 153.]
4. DANA, J. D.—United States Exploring Expedition during the years 1838-42, under the command of Charles Wilkes, U.S.N. Vol. X. Geology. (4to. Philadelphia, 1849.)
   [Brief references to Pennant Hills Quarry, and most interesting descriptions of Prospect Hill.]
5. CLARKE, W. B.—Researches in the Southern Gold Fields of New South Wales. Sydney, 1860.
   [Reference to Prospect, page 248.]

*6. CLARKE, W. B.—"Transmutation of Rocks in Australasia." *Trans. Phil. Soc. N. S. Wales for* 1862-1865, pp. 267-308.
   [Numerous references to dykes near Sydney, and their effects. Discusses prismatisation of sandstone, and refers to several occurrences of it.]

7. CLARKE, W. B.—Remarks on the Sedimentary Formations of New South Wales. 4th Ed. (8vo. Sydney, 1878.)
   [Geological map refers to Prospect Hill, p. 73.]
8. WILKINSON, C. S.—*Ann. Rep. Dept. Mines N. S. Wales for* 1879.
   [Brief description of Pennant Hills Quarry, Appendix A, page 218.]
9. WILKINSON, C. S.—*Ann. Rep. Dept. Mines N. S. Wales for* 1882.
   [Brief reference to the occurrence at Springwood, now known to be a volcanic neck p. 139.]

*10. DAVID, T. W. E.—Notes on some points of basalt eruption in New South Wales. *Trans. Geol. Soc. Austr.*, 1886, I, Pt. 1.
   [Detailed and illustrated account of the prismatic sandstone and dykes at Bondi, with figure.]

*11. WILKINSON, C. S.—Handbook to the Australasian Association for the Advancement of Science. Sydney Meeting, 1887.
   [References chiefly to Prospect and Pennant Hills Quarries. Prismatic sandstone, p. 31.]

12. DAVID, T. W. E.—Cupriferous Tuffs of the Passage Beds between the Triassic Hawkesbury Series and the Permo-Carboniferous Coal Measures of New South Wales. *Rept. Austr. Assoc. Adv. Science for* 1888, I, pp. 34-35.
   [Brief reference to Prospect, page 288.]
13. DAVID, T. W. E.—Micropetrographical Notes on some of the Hydrothermal Rocks of New South Wales. *Rept. Austr. Assoc. Adv. Science for* 1887, I.
   [Reference to Bulli dykes, p. 200.]
14. PITTMAN, E. F.—Report on Site for a new Bore at Cremorne. *Ann. Rept. Dept. Mines N. S. Wales for* 1892, pp. 109-111.
15. DAVID, T. W. E., SMEETH, W. F., and WATT, J. A.—Preliminary Note on the occurrence of a Chromite-bearing Rock in the Basalt at the Pennant Hills Quarry, near Parramatta. *Journ. R. Soc. N. S. Wales for* 1893, XXVII, pp 401-406.

*16. CURRAN, J. M.—On the Structure and Composition of a Basalt from Bondi. *Journ. R. Soc. N. S Wales for* 1894, XXVIII, pp. 217-231.
[Photograph of prismatic sandstone.]

17. PITTMAN, E. F.—Report on Chadwick and Gane's Prospecting Operations at Long Bay. *Ann. Rept. Dept. Mines N. S. Wales for* 1896, Sydney, p. 99.

*18. DAVID, T. W. E.—Anniversary Address. *Journ. R. Soc. N. S. Wales for* 1896, XXX, pp. 33-69.
[Contains much valuable information.]

*19. POWER, F. D.—Receptacles for Valuable Mineral Deposits. *Trans. Austr. Inst. Min. Eng.* 1891, IV, p. 32.
[Photographs of prismatic sandstones at Bondi.]

*20. CURRAN, J. M.—The Geology of Sydney and the Blue Mountains. (2nd Ed. Sydney, 1899.)
[Plan, photographs, lists of localities.]

21. JAQUET, J. B.—The Iron Ore Deposits of New South Wales. *Mem. Geol. Survey N. S. Wales, Geol.* 2, 1901.
[Reference to the Gosford dyke, pp. 117-118.]

22. PITTMAN, E. F.—The Mineral Resources of New South Wales. (8vo, Sydney, 1901.)
[Analysis of clay from the Epping dyke, p. 435.]

23. JAQUET, J. B.—Ironstone Deposits at Long Bay. *Ann. Rept. Dept. Mines N. S. Wales for* 1902. Sydney.
[Plan of the dykes, p. 128.]

24. CARD, G. W., MINGAYE, J. C. H., and WHITE, H. P.—Analcite-Basalt from the Sydney District. *Rec. Geol. Survey N. S. Wales,* 1902, VII, Pt. ii, pp. 93-109.
[Refers principally to the Bondi intrusion and the Moorefields dyke.]

25. CARD, G. W.—An Eclogite-bearing Breccia from the Bingera Diamond Field. *Rec. Geol. Survey N. S. Wales,* 1902, VII, Pt. ii.
[Brief references to inclusions in the basalts.]

26. CARD, G. W.—Occurrence of Nepheline in Post-Triassic Basalts of the Hawkesbury Sandstone Area. *Rec. Geol. Survey N. S. Wales,* 1903, VII, Pt. iii, p. 39.

27. MINGAYE, J. C. H., and WHITE, H. P.—Notes and Analyses of Olivine-Basalt Rocks from the Sydney District. *Rec. Geol. Survey N. S. Wales,* 1903, VII, Pt. iii, pp. 226-230.

VOLCANIC NECKS.

Locality.	Reference Numbers.	Nature.
Bondi	10, 11, 16, 20, 26, 27	A mass of analcite-bearing Olivine Basalt. It is not an ordinary dyke.
Dundas (Pennant Hills)	6, 8, 11, 18, 20, 25, 26, 27	Olivine Basalt.
North Dural	26	Nepheline-bearing Olivine Basalt.
Erskine Park	.....	Agglomerate.
Euroka Creek	18 (with section)	,,
Hornsby	.....	Agglomerate containing large masses of very compact Basalt. The largest of the known necks in the Sydney District.
Menangle	.....	Agglomerate.
The Sugar Loaf Hill, Bargo	.....	,,
Minchinbury	.....	,,
Glenlee	.....	Olivine Dolerite.
Nepean River	3 (page 153)	
Springwood	18	
Prospect.		

References.—4 (498, 509, 515-6), 5 (248), 6 (292), 7 (73), 11 (34), 18 (61), 20 (259), 24 (8), 26, 27.

APPENDIX II.

A list comprising some of the papers, &c., dealing with the geology of the Sydney District is here given. (Those dealing with the intrusive rocks will be found in App. I, p. 272.)

No references are given to papers dealing with purely palæontological subjects.

ANDREWS, E. C.—Notes on the Geography of the Blue Mountains and Sydney District. *Proc. Linn. Soc. N. S. Wales*, 1903-1904, XXVIII, Pt. 4, pp. 786-825, Plates 39-44.

CARNE, J. E.—The Kerosene Shale Deposits of New South Wales. *Mem. Geol. Survey N. S. Wales, Geol. No.* 3. (4to. Sydney, 1903.)

[General references to early observers on Geology of Sydney and Blue Mountains, pp. 26-31; Hawkesbury and Wianamatta stages, pp. 141-151.]

CLARKE, W. B.—Researches in the Southern Goldfields of New South Wales. (8vo. Sydney, 1860.)

[Wianamatta and Hawkesbury stages, pp. 247-250.]

CLARKE, W. B.—Recent Geological Discoveries in Australasia. 2nd Ed. (8vo. Sydney, 1861.)

[Brief references to Hawkesbury Sandstone, p. 29.]

CLARKE, W. B.—On the Relative Position of Certain Plants in the Coal-bearing beds of Australia. *Quart. Journ. Geol. Soc.*, 1861, XVII, pp. 354-362.

CLARKE, W. B.—Remarks on the Sedimentary Formations of New South Wales; 3rd Ed., 8vo. Sydney, 1870; in "Industrial Progress of New South Wales," pp. 505-531.

[References on pp. 519-520. See also 4th Ed. (1878), pp. 70-81.]

CURRAN, J. M.—The Geology of Sydney and the Blue Mountains, &c. (8vo. Sydney, 1898. 2nd. Ed. 8vo. Sydney, 1899.)

DANA, J. D.—United States Exploring Expedition during the years 1838-42, vol. X. (4to. Philadelphia, 1849.)

[Refers at length to Hawkesbury Sandstone.]

DAVID, T. W. E.—The Coal Measures of New South Wales and their associated Eruptive Rocks. *Journ. R. Soc. N. S. Wales for* 1890, XXIV, pp. 257-270.

[Reference to Hawkesbury Sandstone and Wianamatta Shales.]

DAVID, T. W. E.—Notes on the Occurrence of a Calcareous Sandstone at Rock Lily, near Narrabeen. *Journ. R. Soc. N. S. Wales* for 1893, XXVII, pp. 406-407.

DAVID, T. W. E.—[Remarks on Eruptive Rocks of the Sydney District and on Monoclinal Fold at Lapstone Hill], In H. C. Russell's Anniversary Address. *Journ. R. Soc. N. S. Wales for* 1892, XXVI, pp. 36-37.

DAVID, T. W. E.—Notes on the Occurrence of Barytes at Five Dock, and also at the Pennant Hills Quarry, near Parramatta, with a suggestion as to the possible origin of Barytes in the Hawkesbury Sandstone. *Journ. R. Soc. N. S. Wales for* 1893, XXVII, pp. 407-408.

DAVID, T. W. E.—An important Geological Fault at Kurrajong Heights, N. S. Wales. *Journ. R. Soc. N. S. Wales for* 1902, XXXVI, pp. 359-370, Plates 16-17.

DAVID, T. W. E., and PITTMAN, E. F.—Notes on the Cremorne Bore. *Journ. R. Soc. N. S. Wales for* 1893, XXVII, pp. 443-465.

DAVID, T. W. E., and PITTMAN, E. F.—On the Discovery of Coal under Cremorne, Sydney Harbour. *Records Geol. Survey N. S. Wales*, 1894, IV, Pt. 1, pp. 1-7, Plates 1 and 2.

DARWIN, C.—Geological Observations on the Volcanic Islands, and parts of South America visited during the voyage of H.M.S. "Beagle." 2nd Ed. (8vo. London, 1876.)
[Hawkesbury Sandstone in Blue Mountains, pp. 146-154.]

DUNSTAN, B.—On the Occurrence of Triassic Plant Remains in a Shale Bed near Manly. *Journ R. Soc. N. S. Wales for* 1893, XXVII, pp. 378-380, Plate 22.

ETHERIDGE, R., Junr., DAVID, T. W. E., and GRIMSHAW, J. W.—On the Occurrence of a Submerged Forest with remains of the Dugong, at Shea's Creek, near Sydney. *Journ. R. Soc. N. S. Wales for* 1896, XXX, pp. 158-185, Plates 9-11.

JUKES, J. B.—A Sketch of the Physical Structure of Australia, so far as it is at present known. (8vo. London, 1850.)
A brief reference to Geology of Sydney District, pp. 20-24. Similar information is included in the "Student's Manual of Geology." (8vo. London, 1857.) p. 460.

LIVERSIDGE, A.—Preliminary Note on the Occurrence of Gold in the Hawkesbury Rocks about Sydney. *Journ. R. Soc. N. S. Wales for* 1894, XXVIII, pp. 185-188.

RAE, J. L. C., PITTMAN, E. F., and DAVID, T. W. E.—Record of Rock Temperatures at Sydney Harbour Colliery, Birthday Shaft, Balmain, Sydney, New South Wales. *Journ. R. Soc. N. S. Wales for* 1899, XXXIII, pp. 207-224.
[Section of Strata passed through.]

SMITH, H. G.—On Kaolinite from the Hawkesbury Sandstone. *Journ. R. Soc. N. S. Wales for* 1891, XXV, pp. 171-178, Plate 23.

SMITH, H. G.—Preliminary note on Limestone Occurring near Sydney. *Journ. R. Soc. N. S. Wales for* 1892, XXVI, pp. 302-304.

SMITH, H. G.—On Almandine Garnets from the Hawkesbury Sandstone of Sydney. *Journ. R. Soc. N. S. Wales for* 1894, XXVIII, pp. 47-50.

STATHAM, E. J.—Observations on Shell-heaps and Shell-beds. Significance and importance of the Record they afford. *Journ. R. Soc. New South Wales for* 1892, XXVI, pp. 304-314.

STRZELECKI, P. E. DE.—Physical Description of New South Wales and Van Diemen's Land. (8vo. London, 1845.)
[Brief reference to Hawkesbury Sandstone, p. 129.]

TAYLOR, J. E.—Our Island Continent, &c. (8vo. London, 1886.)
[Notes on Geology of Sydney District and Blue Mountains.]

WILKINSON, C. S.—Notes on the Occurrence of remarkable Boulders in the Hawkesbury Rocks. *Journ. R. Soc. N. S. Wales for* 1879, XIII, pp. 105-107.

WILKINSON, C. S.—Notes on the Geology of New South Wales. In Min. Products N. S. Wales. (4to. Sydney, 1882.)
[Hawkesbury Series, &c., pp. 53-54.]
2nd. Ed. (4to. Sydney, 1887.)
[Hawkesbury Series, &c., pp. 72-77.]

WOODS, J. E. T.—The Hawkesbury Sandstone. *Journ. R. Soc. N. S. Wales for* 1882, XVI, pp. 53-116.
[With discussion by C. S. Wilkinson, W. J. Stephens, and A. Liversidge.]

WOODS, J. E. T.—On the Wianamatta Shales. *Journ. R. Soc. N. S. Wales for* 1883, XVII, pp. 75-85.

WOODS, J. E. T.—The Desert Sandstone. *Journ. R. Soc. N. S. Wales for* 1888, XXII, pp. 290-335.
[Scattered references to Hawkesbury Sandstone.

APPENDIX III.

TABULAR STATEMENT of the Dykes recorded from the Sydney District to the end of 1903.

The Roman numerals are those given to the dykes on the published sketch map. The small reference numbers are those prefixed to the works enumerated in the foregoing bibliography.

Except when otherwise stated these dykes are in general decomposed.

Number.	Reference to Literature. (App. I, p. 272)	Strike.	Dip.	Width.	Remarks.
I	.....	.....	.....	.....	Probably a continuation of II.
II	.....	S. 54° E.	N.E. at 82°	2′ 6″	" " XC.
III	.....	S. 70° E.	.....	About 2′ 0″	Joins II.
IV	.....	.....	.....	.....	
V	.....	S. 64° E.	.....	3′ 0″	Deep ravine.
VI	.....	S. 82° E.	.....	2′ 3″	"
VII	.....	.....	.....	.....	Probably a continuation of VI.
VIII	10, p. 34	S. 65° E.	N.E. at 82°	6′ 6″	
IX	20, pp. 259, 261, 272-3	N. 3° W.	.....	About 3′ 6″	Deep ravine
X		S. 65° E.	N.E. at 84°	3′ to 7′	Ravine.
XI	.....	S. 85° W.	.....	4′ 0″	
XI A, B	.....	.....	.....	.....	Probably continuations of XI.
XII	.....	S. 70° E.	E. at 73°	About 6′ 6″	Bends S. 73° E. near the sea. Near by are four small parallel dykes.
XIII	.....	.....	.....	.....	Struck in sewer tunnel.
XIV	.....	S. 72° E.	.....	2′ 6″	Beneath bridge in Tamarama-street.
XV	.....	N. 17° E.	.....	1′ 0″	In Nelson's Bay road.
XVI	.....	S. 70° E.	.....	10′ 0″	At Cemetery.
XVI A	.....	.....	.....	.....	At Queen's Park.
XVII	.....	S. 60° E.	N. at 70°	3′ 0″	At Cemetery; joins XVI.
XVIII	.....	S. 68° E.	.....	5′ 0″	
XIX	.....	About S. 68° E.	.....	.....	Seen in bed of creek.
XX	.....	S. 48° E.	.....	About 2′ 0″	Somewhat problematical.
XXI	.....	S. 80° E.	.....	2′ 8″	
XXII A, B	.....	N. 1½ E.	.....	6′ to 12′	At St. Mark's, Glebe, and Double Bay Gully.
XXIII	.....	S. 80° E.	S.W. at 85°	3′ to 6′	With several offshoots.
XXIV	.....	S. 79° E.	.....	About 4′ 0″	
XXV	20 (pp. 260, 265)	East	.....	3′ 6″	
XXVI		S. 78° E.	.....	1′ 3″	
" A		N. 88° E.	N. at 80°	1′ to 2′	Joins XXVI.
XXVII		S. 69° E.	S. at 87°	2′ 6″	
XXVIII		East	.....	5′ 0″	
" A	.....	.....	.....	.....	Struck in an excavation.
" B	.....	.....	.....	.....	Seen in the cliff.
" C	.....	.....	.....	5′ to 12′	Pursues an irregular course. Worked for clay.
XXIX	.....	East	N. at 80°	About 2′ 6″	
XXX	.....	S. 86° E.	N. at 77°	2′ 4″	
XXXI	.....	About N. 87° E.	.....	About 2′ 0″	Pursues an irregular course.
XXXII	.....	About N. 89° E.	.....	About 2′ 0″	
XXXIII	.....	About N. 87° E.	.....	.....	
XXXIV	17 (p. 99) 20 (p. 259, 265) 23 p. 128, with plan 25 (p. 11) 26, 24	S. 88° E.	.....	About 2′ 0″	A series of four dykes, close together, which may possibly unite. Sound basalt has been obtained in shafts.

Number.	Reference to Literature.	Strike.	Dip.	Width.	Remarks.
XXXV	.....	S. 88° E.	.....	2′ 0″, 3′ 6″ 4′ 0″, 2′ 0″	A series of four dykes which are probably continuous with XXXIV. Worked for clay.
XXXVI	17(p.260)	S. 48° E.	.....	About 12′ 0″	
XXXVII		S. 57° E.	S. at 75°	2′ 9″	
XXXVIII		S. 85° E.	.....	3′ 3″	
XXXIX		N. 84° E.	.....	12′ 0″	
XL	.....	S. 73° E.	.....	2′ 6″	Near north side of Hospital fence.
XLI	.....	S. 70° E.	.....	About 5′ 0″	With a small offshoot.
XLII	.....	East	.....	12′ 0″	Right on beach.
XLIII	.....	S. 82° E.	.....	7′ 0″	
XLIV	.....	S. 76° E.	.....	7′ 0″	A good exposure. Dyke bends S. 63° E. near the sea.
XLV	.....	S. 81° E.	.....	12′ 0″	
XLVI	.....	S. 85° E.	.....	5′ 0″ 1′ 0″ 1′ 0″	A series of three dykes.
XLVII	.....	N. 87° E.	.....	6′ 0″	Bends E. near the sea.
XLVIII	.....	S. 88° E.	.....	10′ 0″	Ravine.
XLIX	.....	S. 80° E.	.....	4′ 3″ to 6′ 0″	
L	.....	N. 89° E.	.....	6′ 0″	Probably continues from near Cape Banks to Botany Bay.
LI	.....	N. 85° E.	.....	2′ 0″	
LII	.....	N. 85° E.	N. at 87°	1′ 6″	
LIII	.....	S. 60° E.	.....	.....	South side of High-street, at S.E. corner of Randwick Racecourse.
LIV	.....	N. 85° E.	S. at 70°	0′ 7″	At "Grosvenor Hotel," Church Hill.
LV	.....	.....	.....	7′ 6″	
LVI	20 (p. 261)	S. 69° E.	S.W. at 85°	8′ to 10′	
„ A	.....	S. 69° E.	.....	18′ 0″	Crown-street.
„ B	.....	S. 69° E.	.....	About 15′ 0″	Riley-street.
„ C	.....	S. 69° E.	.....	.....	Struck in sewer tunnel.
„ D	.....	S. 69° E.	.....	.....	Struck in water-main tunnel, Macquarie-street South.
„ E	.....	.....	.....	.....	Struck excavation for building
„ F	.....	S. 69° E.	.....	N. 10′ 0″ S. 3′ 0″	Two dykes struck in sewe tunnel, Harris-street.
„ G	.....	S. 69° E.	.....	.....	Saunders' Quarry.
LVII	.....	.....	.....	6′ 0″	Struck in sewer tunnel, Quay-street.
LVIII	6 (p. 294) 10 (p. 34) 20 (pp. 260, 261)	N. 10° W.	.....	2′ 0″	Saunders' Quarry.
LIX	.....	S. 78° E.	.....	7′ 3″	Glebe Point road, near Wharf.
„ A	.....	S. 78° E.	.....	4′ 0″	Struck in sewer tunnel, Leichhardt-street.
„ B	.....	S. 78° E.	.....	5′ 0″	In William Henry street.
„ C	.....	S. 78° E.	.....	.....	In Elizabeth-street.
LX	20 (p. 260)	.....	.....	.....	Two dykes formerly visible in the railway cutting at Petersham
„ A	.....	.....	.....	.....	Two dykes in Canterbury-road, near Regent-street.
„ B	.....	.....	.....	2′ 0″	Struck in water-main tunnel, Addison-road.

Number.	Reference to Literature.	Strike.	Dip.	Width.	Remarks.
LXc	.....	.....	.....	2′ 0″	Struck in water-main tunnel, Livingstone-road.
LXI	.....	N. 54° E.	N.W. at 79°	4′ to 5′	Shale quarry, Canterbury new road.
LXII	.....	N. 58° E.	.....	8′ 0″	Duntroon-street.
LXII A, B, C	24, 26, 27	N. 58° E.	.....	About 12′	At Tannery, formerly known as Sayers'. Sound basalt (analcite-bearing) was formerly quarried.
„ D	.....	.....	.....	.....	East of Canterbury Station.
„ E, F, G	24 20 (pp. 59, 258, 259, and photo.)	N. 50° E.	.....	9′ to 12′	Sound basalt (analcite-bearing) was formerly worked.
LXIII	.....	N. 81° E.	.....	.....	Perhaps parallel dykes. Sandstone was formerly worked.
„ A, B	.....	N. 73° E.	.....	8′ to 12′	
LXIV	.....	N. 40° E.	.....	9′ to 10′	Sound stone may be obtained.
LXV	.....	S. 85° E.	.....	5′ to 10′	Clay pits have been opened.
LXVI	.....	.....	.....	.....	
LXVII	20 (p. 265)	.....	.....	.....	In Gentles' Quarry.
LXVIII	.....	N. 30° E.	.....	2′ 0″	
LXIX	.....	.....	.....	.....	Rodd Island,
LXIX A, B, C	6 (pp. 294, 296, 300, 302)	N. 81° E	N. at 81° to 82° E.	6′ to 8′	Exposed in quarries.
LXX	20 (pp. 260-261)	N. 10° E	.....	4′ 0″	On railway at 8½-mile peg, near Concord.
LXXI	10 (p. 34)	.....	.....	1′ 6″	Struck in tunnel.
LXXII	.....	N. 81° E	.....	About 5′ or 6′	Struck in sewer tunnel.
LXXIII	.....	N. 78° E.	.....	8′ to 10′	Henley-road. Sound rock has been worked.
LXXIV A, B	20 (pp. 258, 259), 23, 27	East	Nearly vertical	From 3′ to 4′	Three parallel dykes; the most southern of these is bifurcated. Sound basalt has been worked.
LXXV	.....	N 45° E.	Irregular	.....	Amygdaloidal.
LXXVI	27	N. 40° E	.....	8′ to 10′	Altered dolerite and basalt. Is being worked.
LXXVI A, B	.....	N. 40° E	S.E. at 75° to 85°	About 3′	
„ C	.....	N. 40° E	.....	About 5′	Olivine basalt.
LXXVII	.....	N. 25° E.	.....	4′ to 5′	Sound basalt has been worked.
LXXVIII	.....	N. 25° E.	.....	About 3′ 0″	„ „ „
LXXIX	25 (p. 11)	N. 45° E.	.....	4′ to 8′	Sound basalt (analcite-bearing) has been worked. The dyke is exposed for two miles.
LXXX	.....	.....	.....	.....	Loose pieces of sound basalt have been picked up.
LXXXI	.....	.....	.....	.....	In Flushcombe-road.
LXXXII	20 (p. 67, photograph, and p. 17)	N. 25° E.	.....	About 7′ 0″	Riley's Quarry. Sound basalt has been worked. Indications of prismatic structure may be seen in the neighbouring sandstone.
LXXXIII	.....	N. 10° W.	.....	About 2′ 6″	Burton's Quarry, Sound rock has been worked. Indications of prismatic structure may been seen in the neighbouring sandstone.

Number.	Reference to Literature.	Strike.	Dip.	Width.	Remarks.
LXXXIV	20 (p. 44, photograph, and p. 260)	.....	.....	.....	Well shown in railway cutting.
LXXXV	.....	S. 85° E.	N. at 70°	About 3′ 6″	In quarry.
LXXXVI	.....	N. 10° E.	N.W. at 80°	About 4′ 0″	,,
,, A	.....	N. 10° E.	.....	About 6′ 0″	
,, B	.....	N. 10° E.	.....	About 0′ 10″	
LXXXVII	22 (p. 435)	N. 15° E.	.....	Varies	Worked for white clay. Spongy limonite is adjacent.
LXXXVIII	.....	.....	.....	.....	Probably a dyke. Sound basalt is worked.
LXXXIX	.....	N. 45° W.	S.W. at 80°	10′ to 15′	
XC	.....	.....	.....	.....	
XCI	.....	S. 72° E.	.....	3′ 0″	
XCII	.....	S. 68° E.	.....	1′ 6″	
XCIII	.....	N. 7° E.	E. at 86°	5′ 0″	
,, A	11 (pp. 109, 111)	N. 7° E.	.....	.....	
,, B	20 (p. 261)	.....	.....	.....	
XCIV	.....	S. 52° E. to S. 56° E.	.....	6″ to 4′ 0″	
XCV	.....	S. 60° E.	S. 30° W. at 81°	2′ 0″	
,, A	20 (p. 261)	S. 60° E.	.....	2½′ to 3′	
,, B					
XCVI	.....	.....	.....	.....	
XCVII	.....	S. 72° E.	N. 18° E. at 83°	3′ 6″	
XCVIII A, B, C	6 (p. 298) 20 (pp. 260, 261)	S. 65° E. to S. 68° E.	S.W. at 70°	3′ 6″	
XCIX	.....	S. 60° E.	N.E. at 75°	About 4′ 0″	Worked for white clay,
,, A	.....	S. 10° W.	S.E. at 85°	About 2′ 0″	Joins XCIX.
C	20 (p. 259) 27	S. 47° E.	.....	2′ to 3′	Sound amygdaloidal dolerite. A good example of a dyke. Native copper has been found near here.
CI	.....	N. 45° E.	.....	3′ to 4′	Sound rock has been worked.
CII	.....	.....	.....	.....	
CIII	21 (pp. 117, 118)	.....	.....	2′ to 5′	The outcrop consists of pure brown ore. Has been worked for clay and ironstone flux.
CIV	.....	N. 45° E.	N.W. at 85°	10′ to 12′	Lamb's Quarry. Sound stone has been worked.
CV	.....	N. 45° E.	N.W. at 80°	About 6′ 0″	Lethbridge's Quarry. Sound stone has been worked.
CVI	.....	.....	.....	.....	Exact location uncertain, but shown on the Rev. W. B. Clarke's map.
CVII	.....	N. 40° E.	.....	8′ to 12′	Traceable for at least a mile and a half. Sound stone has been worked.
CVIII	.....	.....	.....	1′ to 2′	
CIX	26, 27	N. 48° W.	S.W. at 85°	About 8′ 0″	Sound basalt (analcite-bearing) has been worked. The dyke is well-defined, and can be traced for three miles.
CX	.....	N. 2° W.	W. at 85°	About 3′ 0″	Sound basalt has been worked here.

Number.	Reference to Literature.	Strike.	Dip.	Width.	Remarks.
CXI	26, 27	.....	.....	.....	Sound basalt has been worked here.
CXII	.....	.....	.....	.....	Sound basalt has been worked here.
CXIII	.....	.....	.....	.....	Basalt is found *in situ* on the railway near the 42-mile peg. The mode of occurrence is uncertain.
CXIV	.....	N. 30° W.	S.E. at 63°	About 2′ 6″	Near the 46-mile peg on Razorback-road. Sound stone.
CXV	.....	N. 30° W.	.....	3′ to 4′	Sound rock has been worked.
CXVI	.....	N. 35° W.	S.W. at 77°	About 3′ 6″	On the railway near 44-mile peg. Traceable for a mile and a half. Sound stone has been worked.
CXVII	.....	N. 35° W.	S.W. at 77°	3′ 9″	
CXVIII	.....	N. 35° W.	S.W. at 80°	2′ 3″	Sound rock.
CXIX	.....	N. 35° W.	S.W. at 80°	1′ 6″	,,
CXX	.....	.....	.....	.....	Loose pieces of sound basalt have been found near by.
CXXI	.....	N. 10° W.	.....	4′ 0″	Struck in water canal.
CXXII	.....	.....	.....	.....	In Bulli Colliery.
CXXIII	.....	.....	.....	.....	,,
CXXIV	.....	Irregular (N. 20° E.	.....	Irregular	In Metropolitan Colliery. A series of four dykes averaging about one chain in aggregate width.
CXXV	.....	N. 82° E.	.....	.....	In Metropolitan Colliery.
CXXVI	.....	Irregular (N. 20° E.)	.....	.....	,, ,,
CXXVII	.....	N. 10° W.	.....	.....	,, ,,
CXXVIII	.....	N. 20° W.	.....	6′ 6″	,, ,,
CXXIX	.....	North	.....	12″ to 4′ 9″	In Metropolitan Colliery. A series of five parallel dykes, varying in width.
CXXX	.....	North	.....	.....	In Metropolitan Colliery.
CXXXI	.....	N. 70° E.	Vertical	About 4′	
,, A	.....	N. 55° E.	S.E. at 32°	About 1′ 6″	Apparently an offshoot of CXXXI.
CXXXII	.....	N. 33° W.	S.W. at 83°	3′ to 4′	
CXXXIII	.....	Irregular (N. 67° E.)	.....	.....	In Coal Cliff Colliery.
CXXXIV	.....	Irregular (N. 10° E.)	.....	.....	In South Clifton Colliery. Two dykes.
CXXXV	.....	N. 70° E.	.....	3′ 6″ to 10′	Hackett's Quarry. Several parallel dykes. Sound rock has been worked.
CXXXVI	.....	S. 55° E.	Irregular	5′ to 9′	Traceable for a mile to the S.E.
CXXXVII	.....	S. 45° E.	.....	About 30′	Sound basalt with masses of olivine and hornblende.
CXXXVIII	.....	.....	.....	.....	Sound basalt; the mode of occurrence is uncertain.
CXXXIX	.....	.....	.....	.....	,, ,, ,,
CXL	.....	.....	.....	.....	,, ,, ,,
CXLI	.....	.....	.....	.....	,, ,, ,,
CXLII	25 (p. 12)	.....	.....	.....	
CXLIII	.....	S. 5° E.	.....	2′ to 2′ 6″	
CXLIV	.....	N. 62° E.	N.W.	About 7′	An offshoot from the east side of the Dundas Neck. Sound rock.

Number.	Reference to Literature.	Strike.	Dip.	Width.	Remarks.
CXLV	.....	N. 10° E.	W.	About 8′	An offshoot from the north side of the Dundas Neck. Sound rock.
CXLVI	.....	N. 44° E.	.....	About 4′	Sound basalt has been worked.
CXLVII	.....	S. 53° E.	S.S.W. at 78°	About 4′	Sound basalt.
CXLVIII	6 (p. 298)	S. 70° E.	.....	.....	
CXLIX	.....	S. 82° E.	S. at 85°	About 5′	Blake's Quarry.
CL	20 (p. 260)	S. 75° E.	.....	2′ 6″ to 3′	Near junction of Rainbow-street and Bunnerong-road.
CLI	20 (p. 261), 23, 24	S. 75° E.	.....	.....	Loose pieces of sound basalt have been found near here.
CLII	.....	.....	.....	.....	Exact location unknown, but shown on the Rev. W. B. Clarke's map.
CLIII	.....	N. 75° E.	.....	.....	
CLIV	.....	.....	.....	.....	Loose pieces of sound basalt have been found near here.
CLV	.....	.....	.....	.....	Sound rock. Mode of occurrence uncertain.
CLVI	.....	.....	.....	.....	
CLVII	.....	.....	.....	.....	
CLVIII	.....	.....	.....	.....	
CLIX	.....	.....	.....	.....	

XXX.—The Geology of the New England Plateau, with special reference to the Granites of Northern New England. Pt. I. Physiography: by E. C. ANDREWS, B.A., Geological Surveyor.

[Plates LV—LVI.]

INTRODUCTION.

THE preliminary note on New England geography was written a year ago.* Since its publication the Writer has been enabled to amplify many of the statements recorded therein, while as the result of numerous aneroid readings and more detailed observations the number of the older plateaus (surfaces of erosion) has had to be enlarged, and their maximum heights above sea-level recorded more accurately. Again, the cycle following on the last great uplift (here called the cañon cycle from the present great prevalence of profound gorges along the eastern aspect of the plateau and referable to that period of activities) is proved to be of much greater age than was originally considered to be the case.† The assumption, in the first report, of a late-

* Rec. Geol. Survey N. S. Wales, VII, Pt. 3, pp. 140–216.
† *Ibid*, pp. 146, 197–216.

Tertiary age for the great uplift initiating the cañon cycle, was founded on the aspect of the denuded Stannifer level in the central area, and from conclusions based on imperfect data as to the ages of the basalts and their great denudation. The individuality of the Stannifer level in areas of easy access has suffered almost complete destruction, the later erosion imposing forms therein closely resembling a slightly roughened warped surface. Thus areas such as Stanthorpe, Tenterfield, Wallangara, and Emmaville were, on account of their appearance (combined with the characteristic absence of the 3,200 feet level), referred to later differential movements of that surface. Repeated later observations have led to the discovery of the level itself in the form of mesas and flanking esplanades of the Mole residuals overlooking the denuded surfaces originally mistaken for it.

A deduction from this extension in time for the cañon period necessitates, from geographical considerations, the removal of the great basaltic demonstration of New England into this youngest cycle, as will be shown later on. Another corollary to the main proposition is that the "leads" not only of Elsmore Valley, Emmaville, Strathbogie, Newstead, and Boggy Camp, but also of the Nine-mile and Ranger's Valley type, may likewise be referred to the cañon period.*

The discovery of this great work accomplished during the cañon period, and originally assigned to the closing phases of Stannifer planation, has necessitated the removal of the initiation of the present cycle of gradation from the late-Tertiary to a much earlier period, even early Tertiary it may be. That, however, must remain an unsettled point at present. The evidence yielded in the future from the fossil contents of the "leads" will give us some measure of the duration in time for the cañon cycle. The resurrection of the old valley slopes will afford geographical data of great value in deciding the relative ages of the "leads" and the close of the Stannifer period. Pre-basaltic dissection in the cañon period was well advanced, though not quite so decidedly as by the present streams.

In the present note the discovery of a fresh peneplain is recorded, viz., the 5,000 feet level. The plateaus as now determined in the positions of maximum elevation are—The Stannifer, about 3,200 feet; the Mole, varying from 3,650 to 3,750 feet; the Bolivia, varying from 4,300 to 4,600 feet; and the Capoompeta, evidenced by peaks rising from 5,000 to 5,300 feet above sea-level.

Another result of more extended observations is the discovery of the extension of the great Bolivia Level further eastwards than was formerly considered to be the case, also its wonderful former extent and present unreduced eastern masses.

* On account of the lithological resemblance of the isolated basalt-cappings of the "leads" to that of the main mass, and also from the sequential forms arising from post-basaltic gradation. Nevertheless the existence of a late Stannifer age for certain "leads" is not absolutely denied, its extreme improbability is, however, shown.

The ability of the series of acid granites here discussed to resist the encroachments of gradation as compared with that of the Tertiary basalts is admirably illustrated in this area, and also the relative instability of the associated basic granites. The resulting wonderful harmonising of valleys with weaker structures argues also at least a double or triple cycle of subaërial erosion.

Another feature of the report is the discussion of the life of a plateau continuously exposed to the effect of subaërial forces, and that, too, when composed of such resistant rocks as acid granites. From the evidence yielded by a knowledge of the ages of the New England granites, and also as to their resistant nature, it seems impossible for any trace of a Palæozoic land surface (even if late Permian) to exist to-day if subjected continuously to the threefold action of weathering, transportation, and stream corrasion.

As shown previously, undoubted criteria of age for the various levels are not yet available, and the Writer, in view of the great future gain to our geological knowledge resulting from the application of the great "searchlight of modern geographical methods" to Cordilleran and associated coastal problems in Australia, would urge the direction of energy to that grand field of geographic work to be found south and west of Sydney, where, owing either to the possession of greater powers of resistance to erosive forces or to younger warping, the plateaus are in a much less dissected state than those in the New England area. Magnificent examples of peneplains can be seen stretching from sea-level to a height of 2,200 feet at but short distances inland. Here they spread themselves magnificently for miles at a common altitude, there they dip at various angles to the horizon, while anon they advance seawards in high-plateau form, as at South Illawarra, and illustrate the extent of marine erosion and its relation to the sub-marine platform and the dominating plateau. Whether the surface rocks be horizontally-bedded Trias-Jura sandstones, gently dipping Permo-Carboniferous lavas or sandstones, highly inclined Carboniferous slates or strongly folded Devonian or Silurian rocks, the same co-extensive surface capped with mesas can be traced for great distances.* All alike are bevelled off by some action limited vertically by a common level. In New England, on the other hand, the advanced stage of plateau dissection, the nature of the Palæozoic complex composing the levels and the late masking of surfaces by basaltic deluges, make geographical studies in that region difficult. While admitting the possibility of correlating the New England plateaus with Queensland examples, the Writer is so far conversant with the geography of the Cordillera as to appreciate the difficulties attendant on such an attempt southwards. A good base from which to trace the probable co-extension in former times

* For example, the cañoned peneplain stretching from Nowra to the Upper Shoalhaven by way of Yalwal, and the peneplains in the neighbourhood of Braidwood and the Pigeon House Mountain.

of the peneplains of this State and Victoria would be in the Hawkesbury or the Shoalhaven areas. These surfaces, admitting of greater facility of interpretation than the New England examples, could be worked out by young geologists. The discovery of undoubted criteria of age for the middle stages of the cañon cycle will possibly accompany a careful search of the "lead" contents. The relative ages of the older peneplains and the cañon cycle initiation will then fall into line from physiographical considerations. A careful study of buried river deposits, such as the "leads" of the Monaro, Shoalhaven, and Victorian areas, combined with observations conducted along the shoreline and coast, would reveal much also concerning the numerous oscillatory movements of the cañon cycle.

The importance of correlating these magnificent peneplains of the eastern States (even if their sedimentary equivalents or exact age be indeterminable) cannot be over-estimated in their bearing on problems of Tertiary and Cretaceous history in Eastern Australia, most of which are at present wrapped in complete obscurity, since in the absence of post-Jurassic fossils the Cretaceous and Tertiary history of the Cordillera has been neglected for possibly more attractive fields of study. A flood of light will be let in, however, on the Jurassic and later history of the Cordillera and coast by the intelligent study of these old high levels, though in the pioneer attempts errors will be unavoidable owing to the enormous area to be considered, the absence of contour maps, the great denudation which has occurred since the last great uplift, and the limited number of workers at present available.

Problems as to the relative values in time of the differential movements of the plateau, coast, and shore area, north and south, as also east and west, will then admit of solution, and also the migration of divides and other details of river history in Tertiary and Cretaceous times; the relation of the Tertiary extrusives (viz., the great western series of Warrumbungle *trachytes*, the New England *basalts*, and the wonderful north-eastern *pitchstones*) to uplift, subsidence, erosion, and each other would be appreciated; the discovery of the origin of the "Great Barrier Reef" of Australia will follow on the study of marine erosion since the inception of cañon cycle activities and a careful examination of the most recent oscillatory movements of that cycle; the approximate position of the shore line at the close of the latest plateau (Stannifer) cycle, the far-reaching importance of marine erosion (as evidenced at Illawarra) since that momentous period, the relation of Eastern Australian sedimentation to movement, and the gradual development of the sub-marine shelf of New South Wales could be shown; while the control of population, the influence on present and past climates by the cycles of uplift and erosion, and the relation of typography to economical mining* would then be manifest.

* For example, the influence of the last great uplift and later cañoning on "secondary enrichments" of ore depo its.

I desire here to cordially thank Mr. D. Cullen of Undercliffe, Mr. A. Telfer of Tent Hill, and Mr. J. Curran of Drake, who kindly placed their wide geographical knowledge at my disposal, and showed me numerous places of interest in the Tenterfield and Emmaville districts.

Description of the Granite Plateaus.

The correlation of the fragmentary high level surfaces in the northern granite area becomes progressively difficult when considered in vertical succession. The Stannifer level (3,200 feet) in central non-basaltic areas occupying areas of relative weakness has been excessively denuded by later stream activities. The much older Mole level, by reason of the intense hardness and non-solubility in acids of the component rocks, shows broad plateaus even to-day in the central areas. The Bolivia survives in *much denuded* mesas and long ridges, while the existence of the ancient Capoompeta peneplain is evidenced merely by various peaks and short ridges.

Location of Plateau residuals and their characteristic appearance.

(a) *Capoompeta Level.*—The more important of the residuals of this ancient peneplain are Mounts Spiriby, Capoompeta, Jondel, Cooloomongera (Pl. LVI, fig. 3), The Night Cap, and the Round Mountain. The four first-named peaks lie from ten to fifteen miles east of the Great Northern Railway Line between Tenterfield and Bolivia, and are situated in the Great Dividing Range; The Night Cap (5,000 feet) lies fifteen miles east of Glencoe; the Round Mountain and the Snowies lie forty-five miles east of Armidale. Other peaks, as Mount Ballandean and the Crown Mountain appear to represent much denuded remnants of this old level. Spiriby and his associates are fully 5,000 or 5,100 feet in height; their composition being of acid granites or rhyolites (Spiriby) of late or post Permo-Carboniferous age.

(b) *Bolivia Level.*—East of the Great Northern Railway Line and in the neighbourhood of the main divide of the State occurs a long winding and much dismantled surface, varying from 4,300 to 4,600 feet in height. It has a great development a few miles east of a line reaching from Deepwater to Guyra, a distance of about seventy miles. Its composition is a very siliceous granite of post or late Permo-Carboniferous age, and is readily recognised by the ordinary bushman as "the belt of high, barren, sandy, black oak, honeysuckle, blackbutt, and stringybark country." Wide flat gaps* occur in the mass, but viewed from a distance it is seen to possess a fairly even sky-line. When traversing this extensive area a marked irregularity of detail is noticeable. Profound cañons, in the case of the Little and Guy Fawkes Rivers as much probably as 3,500 feet in depth, occur

* These, doubtless, mark old "water-gaps."

immediately to the east. Beyond these again a couple of other even sky-lines mark its further former extension. A remarkable fact is the typical absence of this great level west of the railway line. Mount Mackenzie (Pl. LVI, fig. 1), 4,300 feet in height, is probably one of the few western residuals. The composition of Mackenzie is also of siliceous granite similar to that just described. The philosophy of this eastern survival of the Bolivia level will be discussed when dealing with the migration of divides.

The Mole Level.—The Mole, like the Bolivia, is to be sought chiefly in the coarse acid granite of very late Permo-Carboniferous or early Mesozoic age. It has a great development north of Emmaville and west of the northern railway between Bolivia and Deepwater. (Pl. LVI, figs. 1 and 2.) Here it forms a plateau from 3,600 to 3,750 feet in height. Its sky-line is much more perfect than that of the Bolivia Plain. North of Tenterfield another great residual of this granite level occurs. Here it appears to be about 3,700 feet above sea-level. Again east of Tenterfield, near Timbarra, along the Gibraltar Range, and east of Glen Innes to Mt. Barney, Paddy's Land, Little River, Mitchell River, great residuals of the Mole are associated with the higher and more dissected level of the great Bolivia peneplain. In this eastern area the ridges and mesas consist of indurated slates and acid granites (Gibraltar Range).*

The Stannifer Level.—This was well developed on the eastern and western aspects of the ranges formed by the older residuals, and it even succeeded in establishing itself in the present area of maximum elevation. Withal, however, it was not long-lived like the two preceding types, as it had time sufficient only to carve plains of moderate extent in the more unstable rocks of the granite area. Owing to this fact, and the length of the later cañon period, it is found only on search in the resistant northern areas.

Residuals may be seen following the railway line from Wallangara to Stanthorpe. The hills rising to general height of 500 feet above the latter township, mark points on this surface. From Stanthorpe to Wilson's Downfall, thence easterly to Undercliffe, and southwards to Boonoo Boonoo, a fine example of this level occurs. Looking easterly from the Sugar Loaf Mountain on the Queensland border, and westerly from the watershed of the Tooloom and Koreelah Rivers (Pl. LV) a striking impression is obtained of a surface showing an even sky-line for some twenty miles north and south. This in the hard granite area. Thence to the east in the incoherent Trias-Jura sediments it apparently stretched formerly in unbroken sweep to the coast.

* This may hereafter prove to belong to the Bolivia Level.

Other denuded residuals of this old land surface occur under Mount Mackenzie, near Tenterfield, also in the neighbourhood of Bolivia, while in the slate, granite, and porphyry country round Dundee* and Deepwater it has a great development. (Pl. LVI, fig. 3.) It, however, here carefully avoided the siliceous granite. Other fragments of the 3,200 feet level occur at Tent Hill and Emmaville, forming the long ridges and hills rising to a general height of some 300 feet above the last named township,† also at Tingha. (Pl LVI, fig. 4.)

Before proceeding to the discussion of the cañon cycle a few sentences may be devoted to the philosophy of denudation, as illustrated by a study of the extent and composition of the plateau remnants.

The ancient Capoompeta surface, surviving now in a few cones and short ridges only, reveals this fact alone at present, viz., the existence formerly of a surface of erosion, which appears to have been elevated from 7,000 feet upwards above sea-level, and out of which the Bolivia plain was carved. Concerning its age also, we know that it considerably post-dated the Palæozoic, since its composition is of post-Permo-Carboniferous intrusives. Beyond this it preserves an aspect inscrutable as that of the Sphinx. Whether plain or peneplain it is impossible to state. The general height to which the peaks rise, however, would argue at least the old age dissection of a plateau.

The Bolivia Peneplain.—Various isolated surfaces have been referred for the present to one peneplain. Some, as in the neighbourhood of Tenterfield, have a height of 4,300 feet, others, as near Bolivia, Oban, and east of Glen Innes, possess heights about 4,500 or 4,600 feet. Although possibly not referable to one cycle of activities, it has been deemed advisable for the present to so group them. Warping may possibly be called in, or uneven reduction, to correlate the small variations in altitude.‡ Assuming then these areas as a formerly continuous level, a well-advanced phase of a cycle of sub-aërial erosion is here indicated, seeing that the central areas have suffered such reduction over hard and weak structures alike. The main divide of the period is with difficulty located, owing to the later and extensive Mole denudation. The disposition of the Capoompeta residuals, and the development of the Mole peneplain point to its location westwards of the present divide.

* This great plain, as also the Sandon plain around Hillgrove, Armidale, and Uralla, must be placed in the "Plateau" cycle.

† Another table-land called "No Man's Land," lying north-west of Glen Innes, appears to belong to this level. Aneroid measurements are necessary to decide whether Mole or Stannifer, however.

‡ It must be expected that in all but areas of fairly complete planation there would necessarily be a more or less pronounced slope seawards. In this connection the valley of the present Peel at Tamworth is instructive. Here a plain-like surface, some fifteen miles wide, has been induced in the ranges during the cañon cycle. Its height, however, is 1,300 feet above sea-level, to which it gradually falls, thus showing a pronounced slope from east to west.

The Mole Peneplain.—The great extension of the group of plateaus approximately 3,700 feet (3,650–3,750 feet) in altitude indicates the "easy old age" of streams, which had developed a great plain but slightly raised above sea-level. The reduction to base level is not nearly so pronounced as in the case of the Bolivia surface, for long winding sub-horizontal masses of the older level still overtop and border the Mole peneplain in the central areas. A migration to the east is shown for the main divide, thus probably evidencing the imposition of differential uplift causing a steeper fall to the west. This development of western plains of erosion and the great width of the Bolivia level to the east roughened by moderately-sized valleys only* is very pronounced, and marks the variable influences of denudation east and west of the divide; the slope of greatest angular value being to the west, as also, in all probability, the shortest direction to the sea. To the north, in the neighbourhood of Stanthorpe and Tenterfield, the Mole peneplain had established a wide passage through to both eastern and western seas. Insignificant residuals of the Bolivia level alone remained, and between these existed a ridge just sufficiently important to be called a divide. To the weak Trias-Jura system east and west of the narrow granite area here, in this early stage of our knowledge, may be credited this abnormal growth of the Mole plain. Another area which is here doubtfully referred by the writer to the Mole peneplain is that plateau country between Deepwater, Emmaville, and Inverell, known as "No Man's Land." Until its altitude is taken it cannot with certainty be referred to either Mole or Stannifer activities.

Southwards, in the area bounded by the Mitchell River on the east, and a meridionally disposed line fifty miles in length ten miles east of the Northern Railway line between Tenterfield and Glen Innes, the competence of the acid granites and indurated slates to resist the encroachments of the Mole forces is well seen.

The Stannifer Level.—The extent and habit of this level shows a marked decrease in age as compared with that of the great Bolivia level, or even that of the Mole. Over hard and soft strata alike, in the centre as well as on the outskirts of the plateau, the softened contours of the Bolivia peneplain are shown, with the peaks of the Capoompeta peneplain overtopping them after the similitude of anthills dotting an otherwise unbroken surface (Pl. fig. 3), which can, however, be seen to have been at one time co-extensive. The Mole level, also, is seen to traverse hard and soft strata indifferently, its inferior age to the Bolivia being, however, evidenced by its incompetence to produce broad plains in the hard central areas as the Bolivia had done. It will be well to make this point a little clearer, in view of the objections that have been advanced against the conclusions here set forth, viz., that the successive periods of gradation from the Bolivia onwards have been

* The various belts of the Bolivia residuals are separated, however, by profound valleys, some 3,000 feet in depth in certain cases 3,500 feet in depth. Examples—Mann, Guy Fawkes, and Little Rivers.

progressively short-lived. "How is it possible," it has been asked, "to prove that the Bolivia level possessed such an extension formerly as is claimed for it, when the Mole level is declared to have occupied an area not so great, truly, but yet comparable with that of the Bolivia itself?" "How, also, is it possible to predict that the Bolivia peneplain was once continuous over areas now occupied by Mole, Stannifer, and cañon cycle residuals; areas, indeed, which are by definition, those in which there can be no *trace* of Bolivia remnants?" "And, finally, how can the old limits of the Bolivia level and Capoompeta residuals be even approximately set out in the face of the increasing erosion, with consequent loss to residuals during the successive Mole, Stannifer, and cañon cycles?"

Let us consider, in the first place, the aspect of a peneplain, such as the Bolivia, at the close of the cycle. A nearly level surface, presenting a gentle curvature to the sky, and dotted over with subdued mountains is seen. The aspect is thus given of an esplanade overtopped by dome-shaped masses. Upon elevation, in hard homogeneous rock areas as the granites of northern New England, the further formation of the esplanade is discontinued, and destruction of the level with the formation of cañons and valleys becomes the expression of the forces augmented by uplift, and a fresh attempt is made to reduce the whole area to base level. So long as the monadnocks are surrounded by the esplanade (without sensible reduction of the esplanade at junction of the same and the residual) so long may we be sure of the non-material reduction suffered by the residuals. It is immaterial how the esplanade (old plain) is dismantled, whether reduced to broad even-topped ridges, furrowed mesas or the like, while the monadnock rises clear of the broad sweeping ridge or mesa, no great loss has been suffered, and the approximate former limits of peneplain and monadnock can be set.

Secondly, monadnocks belonging to the advanced stage of a cycle are, by the nature of the case, the survival of the fittest, and therefore those portions of an old plateau calculated to be affected but slightly during a succeeding and briefer cycle of erosion, especially if, as is generally the case in areas of uniform uplift, the monadnocks are well situated as regards their own preservation.

Again the existence, not in one limited locality, but over the whole of great areas, of long winding ridges and mountain masses, of a surface showing excessive irregularities of detail, it may be, but, nevertheless, presenting the same even sky-line and common level, argues a former great co-extension of plain (over later valleys and plateaus alike), of which the present ridges, mesas, and masses are the trifling remnants. For, if not, the only alternative is to assume that the later streams on uplift attacked and, in fact, wore away the strong higher monadnocks in the former inter-ridge and mesa areas preferably to reducing the raised plains themselves, which, latter by their very appearance have been demonstrated to be the least competent to resist

the action of the old streams. This is an absurdity from the very nature of stream action, for on even uplift an old raised plain will be reduced before the harder, higher, and more favourably situated monadnocks. So that if one stands on a far-stretching high-level surface, which occupies all but the central and isolated marginal portions of an area, and perceives that these higher surrounding portions consist of numerous level-topped ridges and mountain masses overtopped in turn by cone-shaped monadnocks, then he must assume that the old plain indicated by these surrounding even-topped residuals was once co-extensive over the area now occupied by the newer and lower level on which he stands. Thus, although long since destroyed, except in the more stable areas, the existence of a former plain of denudation can easily be proved from a knowledge of the unfailing laws of stream development. This has been the case for New England. In the centre are the long ridges and furrowed mesas rising from a little above 4,000 feet to about 4,600 feet in height, to which has been given the name of the Bolivia peneplain. Above these in turn rise such peaks as Spiriby, Jondel, Cooloomongera, The Night Cap, and the Round Mountain. Not so, however, east and west of this central area, since Mole activities were competent in those extra-median areas to remove the Bolivia plateau. Incapacity to accomplish its aim, viz., complete Bolivia reduction, was the result of rejuvenescence of uplift before it had run the time occupied by Bolivia action. Entire destruction of Bolivia residuals by Mole grading would have resulted in our utter ignorance as to the existence even of the great Bolivia cycle, except as revealed by associated sedimentation.

Inasmuch then, as the Bolivia was enabled by extension of time to reduce in great measure the stronghold of the Capoompeta, to wit, the central granites, it must have, from corrasive considerations, long prior to that period, reduced the weaker marginal areas. The presence, therefore, of the Mole east and west of the Bolivia, with unreduced central Bolivia portions, demonstrates the greater importance of the older level.

In a like manner the appearance of the Capoompeta residuals argues their minor reduction only in later times.

Similarly the Stannifer* built itself principally at the expense of the Mole; the cañon cycle valleys also at that of the Stannifer, their duration in time being comparatively restricted, the weaker areas alone suffering. The result in northern New England is a most wonderful coincidence of stream directions with the trend of structural weaknesses, a remarkable proof of the claim made by American geologists† of sub-aërial carving characteristically for plateau formation.

* The areas formerly assigned to Stannifer and Sandon activities must now be reduced in light of the evidence of the basalts and referred to the Plateau cycle.

† W. M. Davis, Geographical Journal, 1895, V, No. 2. The Development of certain English Rivers.

Adverting to the description of the Stannifer forces, it will be seen, in the first place, that Stannifer level extension is such as to exclude any claim to great age of the cycle of activities producing it. East and west great remnants of the Bolivia exist, as also those of the much younger Mole peneplain.

In the second place, its very existence in the weaker rocks of the district only (save in the case of the extreme north), sufficiently explains its great comparative youth, since, if long-lived like the Bolivia, it would have spread itself grandly in the centre of the plateau over hard and weak structures alike. Thus, at Deepwater, it excavated a plain in the slates, more basic granites and porphyrites, while carefully avoiding the hard youthful granites. In the Tenterfield and Bolivia districts it had been successful only in establishing a limited area in the old and basic variety of granite, whereas Mole and Bolivia alike had here broadened their plains in the very stronghold of the granites.

On the other hand, certain observations indicate its great absolute age. West and east of the central area it had developed wide plains irrespective of hardness or resistance to erosion, as witness its advance eastwards through the Emmaville locality, and its almost complete occupation of the hard granite areas of Stanthorpe and Wilson's Downfall, where, owing to the instability of the marginal Trias-Jura rocks, it had been permitted to attack the hard central rocks at an early stage, and establish broad passages therein.

The divide in this period appears to have migrated eastwards in the main, with local shift to the west in the extreme north.

The Cañon Period.

Along the coastal area and the western limit of the plateau the denudation of the surface has been so extensive in hard and weak structures alike that any attempt in these localities to construct a scheme for the old peneplains would be impossible. No mesas exist, and thousands of wild ravines with separating knife-edged ridges occupy the greater part of the area of the Clarence, Richmond, Gwydir, Severn, and Macintyre streams along their lower courses.

In the weaker rocks of the central development of the Stannifer level the erosive forces of the cañon cycle have been so long continued that its surface has at times been denuded to the extent of several hundred feet vertically, and so as to present "rolling downs" appearances. Naturally during this reduction of weaker Stannifer areas the Capoompeta, Bolivia, and Mole residuals have suffered immaterially from their very nature as "monadnocks" of the Stannifer.

The imposition of uplift possessing a valuable axis of movement as compared with that of the former period of gradation is evidenced by the migration westward of the old divide in the cañon cycle.

The order of events for this period appears briefly to have been as follows :—

(*a*) Close of Stannifer cycle by moderate uplift and accompanying formation of cañons.

(*b*) The basaltic period, composed of :—

1. Minor visitations followed by moderate erosion.
2. Lava inundation of New England with moderate subsidence.

(*c*) Widespread erosion with formation of wide shallow valleys. The Plateau cycle. Most of the former "Stannifer" levels are to be referred to this cycle.

(*d*) Long continued and pronounced elevation accentuated eastwards of the old divide (still going on), and revival of strains with formation of profound eastern cañons. The Cañon cycle.

The slow uplift which closed the Stannifer cycle probably reached a maximum of 1,500 feet in the broad central areas of uplift. V-shaped cañons early became the expression of the incising action of the streams. The old sluggish Stannifer conditions were soon effaced. The unstable strata were attacked in the inclined Palæozoic and horizontally disposed Jura (?) beds. At a point when the cañons had established themselves and were passing into broad-bottomed valleys, the great Tertiary display of volcanism ensued for New England.

The Basaltic Period.—The more salient points only of this visitation as it affected the area under consideration are dwelt upon, the fuller discussion of the basalts and their topographical significance being reserved for a future report. The fairly advanced stage of plateau dissection attained before the commencement of the lava is shown by the relative vertical positions of the Stannifer level to those of the pre-basaltic and present watercourses in the Emmaville and Inverell districts.

At Elsmore the old river bed (pre-basaltic stream) is about 200 feet below the present bed of the Macintyre, and more than 1,000 feet below the Stannifer level (unless much warped in this locality), and this, too, in the immediate neighbourhood of the central plateau. At Emmaville the old valleys have been carved 300 or 400 feet below the level of the most recent plateau surface, while at Strathbogie the valleys had been cut nearly 1,000 feet below the Stannifer level. Here also the present Severn is in one place still excavating the basalts* (1,000 feet below the Stannifer), and the present Macintyre at Inverell is flowing through basalt rocks of the cañon cycle age.

Therefore we are confident that at a period in the cañon cycle when plateau reduction had been well advanced basalts began to make their appearance in the southern portion of the area under consideration.† At the first these flows appear

* T. W. E. David. Geology of the Vegetable Creek District (Mem. Geol. Survey N. S. Wales, Geol. 1, 1887.)
† The proofs of the cañon period age for all these great basaltic floods will be the subject of a future paper.

to have been but moderate in amount, as is evidenced by a study of the old channels. Shafts and drifts have been excavated in the process of mining the rich stanniferous "leads" of New England, and in the course of these mining operations successive river channels have been exposed containing layers of pebbles in variable degrees of comminution, each river bed being separated by a sheet of basalt.* Each layer of river gravel consists essentially of pebbles of Palæozoic rocks, such as granites, slates, zircons, tinstone, &c., and is characterised by the absence of basalts in quantity. River drift of necessity must be a reflection of its surroundings, thus the limited extension in space of those earlier outbursts is shown, otherwise if of great extent—as the later deluges of New England—the stream pebbles would be of basaltic nature rather than of granitic types. Nor can the idea of widespread denudation occupying inter-basaltic periods be held, since when found those old stream beds lie above each other separated by thin sheets of basalt only. The various degrees of comminution shown by the drift pebbles argues a marked variability of stream erosion in inter-basaltic periods.

Following on these preliminary outbursts† came the mighty basalt deluges of New England. Historically the time consumed between the first and the later grand floods of lava must have been considerable, yet geologically its value is insignificant—as it represents but a very minor fraction of such a young cycle even as the cañon period; thus the basalts should be considered under the head of one visitation. The later deluges were separated by definite periods of time, as revealed by a study of their surfaces. Scores of sheets were poured over each other successively, without sensible loss, however, to each surface before the imposition of another floor. In vertical succession at any place of observation, as at Guy Fawkes or Ben Lomond, one sees ropy surfaces overlain by markedly columnar basalts, these possibly by amygdaloidal varieties, compact or coarse, again by coarsely porphyritic or fine-grained olivine varieties. Inclined prisms, vertical columns, vesicles, zeolites, porphyritic felspars, doleritic varieties, and other peculiarities characterise successive flows. The flows are seldom of abnormal thickness—100 feet is an exceptionally thick sheet, as witness the Ebor Falls at Guy Fawkes where in a 350 feet face as many as seven or eight distinct flows can be distinguished. Remarkable variations in resistance to erosion are shown by a study of the flows, some weathering rapidly to clay, others resisting the attacks of weathering for considerable periods, and thus giving rise to great local levels best described as *benches* of erosion.

From Inverell, Wellingrove, and Glen Innes to a point well south of Scone on the Hunter the lava sheets appear to have been fairly well spread over New England,

* For details as to the method of occurrence of these "leads" and their contents the reader should consult the "Geology of the Vegetable Creek District," before-mentioned.

† How many of these premonitory flows occurred we are unable to state, owing to the extreme denudation suffered since by the basalts east and west of the central area.

filling the marginal valleys. Certain localities received greater thicknesses of lava than others (caused by overlapping of various central displays). In the northern and central areas the heights of the uppermost basalt layers above sea-level exceeded 5,200 feet. The area affected probably exceeded 10,000 square miles, and the average depth of the lava in many places probably approximated to 1,500 feet or more. The increase thus gained to the central plateau was enormous, and if to this be added the other lavas of the cañon cycle, viz., the trachytes and associated rocks of the Nandewar and Warrumbungle Mountains, and the associated pitchstones and basalts of the Tweed, Richmond, and Clarence Rivers, the gain to the land must have been thousands of cubic miles. Whether explosion craters or dykes supplied the greater portion of these enormous flows has not yet been ascertained. But from whatever source supplied the horizontal disposition and great superficial extent of the individual beds argues their wonderful fluidity. Explosion craters appear, undoubtedly, to have been in evidence during the earlier stages preceding the later mighty deluges. For example, a small crater some 300 yards in diameter was observed in the bank of the Macintyre River at Inverell itself. The rim is partly dismantled, and is formed of ferruginous bauxite (?). It was completely buried under the later lava flows, the corrasive action of the Macintyre now, however, gradually exposing it to view.

Earlier than these again there may have been craters and lava streams in the cañon period, but if so there is no evidence as yet of their existence. The tin and gold "leads" of the Stannifer level appear, in every case, to represent the burial of rivers on still unreduced portions of the Plateau cycle surface and higher levels, these "leads" being doubtless in many cases continuous with the eastern and western channels excavated many hundreds of feet below the 3,200 feet level. As mentioned before, a considerable period of time elapsed between the early and closing phases of the lava floods, and "leads" on the 3,200 feet level may have been eroded in part before the final deluges. Nevertheless there appears to be no necessity to separate the basalts other than into minor and greater manifestations of a lava display belonging to a small division only of the cañon period. When the great loss to the later lava floods by denudation is appreciated—a loss probably exceeding a thousand cubic miles of material outside the great cañoned area of the steep eastern fall—then, and only then, can the wonderful importance of the cañon period be understood.*

* These and the following notes are based on the assumption of a very fluid lava display, referable possibly to dyke rather than to crater agencies. On the other hand, it may be urged that the present peripheral portions of the lavas mark, approximately, their original horizontal limits. Also, that many lavas, as those of Inverell, Glen Innes and Ben Lomond, which appear to be continuous, may yet belong to periods of activity often far removed in point of time, the outbursts being local and not connected directly with each other. The mass of evidence, however, points to enormous denudation of great sheets of lava, originating in several centres as Guy Fawkes, The Macpherson Range, The Upper Hunter, the Nandewar Ranges, Ben Lomond, and the Upper Peel River, not far removed in point of time.

The pronounced erosion succeeding to the basaltic period can be but briefly dwelt upon. The sequential forms are highly important and instructive. Instability is a marked feature, being in great measure an expression of pronounced basicity. Certain layers yielded readily under stress of weathering, and allowed of trenching or formation of esplanades in the lava areas, these lower controlling planes being determined by more resistant flows. Prismatic structure led to wholesale degradation, while recession of the lava sheets received a decided check in the denser layers. At Guy Fawkes and Ben Lomond a great bench was set up at the 4,700 and 4,300 feet levels, others at 4,000 feet and still lower levels. Finally the old irregular underlying surfaces of the Palæozoic complex were exposed, bringing into view the buried monadnocks.

It is difficult for the casual traveller, even in the central area—that of minimum denudation—to reconstruct from the scattered lava remnants the former magnificence of the basalt flows. A couple of observations will throw further light on this idea of a series of lava inundations originating in five or six distinct sources and overlapping each other to form an almost continuous sheet of basalt (of varying thickness, however) over New England and associated areas. Benching of the basalts from the 5,000 to the 4,300 feet level has been instanced for Ben Lomond, Guyra, and other areas. Glen Innes, Glencoe, Stonehenge, and allied valleys lie 1,500 feet below the summits of the basaltic Ben Lomond and Mount Rumby Mountains; they occupy broad valleys several miles in width, and are hemmed in on two or three sides by enormous rampart-like prolongations of the basalt sheets. Hence denudation to the extent of from 1,000 to 1,500 feet for the basalts must be granted here, since in numerous instances the basalts still form the valley floors. Advancing westwards to Inverell from Glen Innes, a wide valley with ever-increasing depth is followed for forty-two miles, with the same long winding basalt ridges rising to great heights on both sides for the greater part of the distance. All the way to Inverell (1,950 feet only above sea-level), and for many miles further westwards the basalt may be seen *in situ*, and lithologically indistinguishable from the whole series of central manifestations. Naturally the greatest denudation would occur in the Inverell locality, seeing that it is situated along the bank of the Macintyre—the main stream of the district. Moreover, it is situated along the western fall of the plateau. At Guy Fawkes' Lookout* the observer stands on an easterly-facing rampart of basalt about 1,500 feet in height, overlying the remnants of the Mole and Sandon levels, and descending coastwards to the north-east in a series of benches or plateaus known as the Dorrigo Plateau. Southwards similar enormous basaltic masses occur east of Walcha, forming other precipitous eastward facing escarpments. These two great basaltic masses

* E. C. Andrews. Tertiary History of New England. These Records, VII, Pt. 3, pp. 160–163.

gradually approach each other in the form of huge benches or terraces, dying away finally on the Sandon level. In this portion of the Plateau cycle level, occupying the inter-basaltic area, lies the magnificent cañon of the swift and strong Macleay. Here, then, evidently, the basalts were formerly continued across the inner and outer cañons of the Macleay. The action of the strong Macleay benched the unstable lava flows until the "Plateau" level was reached, after which in turn the deep inner cañon (Cañon cycle) was excavated.*

Equally instructive and impressive are the lessons taught by the Upper Hunter, where the innumerable remnants of the plateaus are all covered with thick basalt cappings, showing undoubted former continuity of the lava plains across the wide-bottomed valleys occupying the intervening spaces.

If then, in areas specially exempt from the marked corrasive influence of streams, such great basalt benching has to be recorded, how much more—granting the western extension of the lavas—must this have been the case away from the area of least slope, where, owing to cañon grade, the efficiency of stream transportation and cutting is wonderfully increased. The pre-basaltic cañons of these extra-central areas, filled to overflowing by the fiery floods, would gradually be unearthed, and have their old rugged profiles exposed under the torrential action of the post-lava streams. Digging deeply into the basalt valleys the erosive agencies brought the old river beds in turn to light. Naturally the imposition of a fresh mass like the basalt showing horizontal layers of varying powers of resistance to erosion over the heterogeneous Palæozoic rocks caused the frequent non-coincidence of present and pre-basaltic channels, that is of superimposed and subsequent or consequent courses. Yet in many cases later stream action has proved incompetent for the task, and the old river beds still lie below their sphere of attack.

Still other evidence of their former great extension superficially and vertically will be given when discussing the basalts more fully, and the marvellous story of the oscillatory earth movements and pre-basaltic geography preserved to us by their action.

Consequent upon the appreciation of this enormous denudation of the basalts and associated rocks in regions of moderate relief only is the granting of great age for the cañon period, involving, as it does, the double excavation of the flanking valleys of the plateaus, the first time in the elevated Palæozoic complex, the second time in re-excavating and broadening the channels in the later lava-filled examples.

A long period of comparatively stable equilibrium succeeded to the oft-repeated aggrading action of the basalts. The basalts were benched, while in the areas less affected by the lavas, as about Tenterfield, Bolivia, and Stanthorpe, the weaker

* Strong evidence of post-basaltic uplifts is evidenced by Macleay studies.

slates and granites were attacked strongly. Naturally, here, the Stannifer peneplain, as the expression of maximum impotence in the old complex, yielded more readily under the stress of erosion, and in certain localities was reduced below the level of basalt-capped remnants of drift specially well situated as regards immunity from stream attack. Thus in places "leads" capped by the most resistant of the basic flows stand above the slightly denuded Stannifer level, as also areas approximately reduced to that level, a fact which led formerly to the postulation of an immense double basaltic* demonstration, viz., a Stannifer and a post Stannifer period display.†

After this long period of subsidence, stable equilibrium, and denudation, the latest great uplift of New England took place. The resultant structures induced in the area under discussion show that the oscillations of movement were long continued, now of uplift, again of subsidence, but always excessively slow in character, and emphasising the eastern as compared with the western slope. Doubtless all the great cycles considered in this report were formed by slow varying movements, but distance in time has permitted of the detailed records being effaced. The basalts cover river deposits which reveal a similar state of things:—Rivers once cascading seawards, then alternating conditions of rapid, shallow, and calm conditions crowned by a great subsidence emphasised centrally, which permitted of lake-like expansions of the rivers and the formation of extensive masses of carbonaceous clays.

The general result of the post-basaltic movements was elevation, probably approximating to 3,000 feet. The streams which had worn wide valleys in the basalts and associated valleys now became revived, deep and profound cañons now working their way westwards along the wide shallow outer examples. This is admirably exemplified in the case of the Macleay. Here the great winding granite mass of the Snowy Mountains at Guy Fawkes and Paddy's Land constituted the pre-basaltic divide. The basalts preserve traces of "leads" running west thence. The imposition of the basalts and the accompanying earth movements allowed the swiftly falling Macleay to encroach on western waters by way of Carrai and south of Guy Fawkes, until it developed broad valleys of moderate depth, as may to-day be seen at Walcha, Hillgrove, Wooloomumbi, and Tia. Then came the great gradual uplift and the wondrous cañons of the Apsley, Tia, Baker's Creek, Chandler, Wooloomumbi and Yarrowitch began to form along their old directions, gradually retreating westwards until the plateau has been almost cut up now eastwards into an impassable plexus of gorges,‡ yet utterly insignificant in age as

* *Vide* "Outline of Tertiary History of New England." already quoted.

† *Ibid.*, pp. 200, 201, 207.

‡ Doubtless all this will be found applicable to the wonderful growth of the Hawkesbury River in the Blue Mountains, viz., that the cañon cycle is divisible there into several distinct periods; that the old Lapstone Hill grant was the Hawkesbury of the post-basaltic period; and that the revived Hawkesbury is of similar age to the revived Macleay and Clarence Rivers of the north.

compared with that of the earlier and outer valleys in which they flow, or with those pre-basaltic and western flowing streams which mark the beginning of the cañon period.

The pronounced shifting of the main divide is evident at once to the thoughtful observer. The great ridges of resistant granite lying many miles east of the present much more lowly situated divide mark an old water-parting. Then came the unstable conditions imposed by the lava deluges, and the western retreat of the divides following on differential uplift. Collateral evidence of this migration of divides is also furnished by a study of the old "leads."

Especially marked is this migration of divides and the revival of stream action in the case of the Southern Clarence. East of Deepwater and Bolivia, however, in extra-basaltic area the lofty and acid masses of Spiriby, Capoompeta, Jondel, Coolomongera, and the Magistrate maintained their positions, and thus the divide here has been constant throughout long ages.

The piracy of streams in olden and more modern (basaltic and post-basaltic) times is here shown magnificently. As an instance may be cited the case of the valley of Bald Nob, east of Glen Innes, 4,000 feet high and two miles broad, where the eastern streams have captured a western watercourse.

The fleeting life of a peneplain, even when developed in rock structures most fitted to survive the shocks of erosive assaults, is well exemplified in the case of the granite levels of New England. The Writer, as a result of numerous observations conducted at Tenterfield, Wilson's Downfall, Rivertree, Boorook, and Tooloom, and the determinations of various fossils therefrom by Mr. W. S. Dun, has been able to assign a Permo-Carboniferous age to a great tract of country in the area under consideration. Certain of the beds possess a Lower Marine facies, while other higher beds suggest an Upper Marine age. Repeated granite and porphyry intrusions of these beds occurred during a later mountain-making period, the order of intrusion observed being, characteristically, decreasing basicity. The end products of this magmatic differentiation consist of coarse and fine-grained granites and porphyrites, the fine-grained granite post-dating the coarse variety. With both of these tin is associated, and lithological studies prove their wonderful development throughout northern and central New England. These granites it is which survive to-day in the peaks of the Capoompeta, the ridges and sub-horizontal summits of the Bolivia, and the plateaus of the Mole level.

Yet it can be proved that the Permo-Carboniferous had been deposited before their intrusion (thus bringing their age into the close of the Palæozoic), and that they themselves in great measure furnished the material of the Trias, for the Trias-Jura sandstones overlie these post or late Permo-Carboniferous granites. Clearly

a great period of denudation ensued before these acid plutonic masses were so much as exposed. More perfect denudation in later times gave rise to the Capoompeta plain (peneplain) represented now by isolated peaks only. Thus the age of this old land surface must be referred to a period much younger than the close of the Palæozoic. Still further the evidence to hand is not sufficient even to warrant the assumption that the Capoompeta itself was the first level established in the granite core after removal of the mighty cap of sediment which occupied the upper portions of the mountain ranges formed by the earth movements closing Palæozoic sedimentation. Speculation is confined to the evidence afforded by various peaks 5,000 feet in height, dotting the Bolivia level in the region of central elevation, and composed of post or late Permo-Carboniferous granites. These demonstrate the wonderful planing off of the upper granite masses, whereby a surface fifty or sixty miles across must have been induced in these rocks. This alone points to a wonderful gap between the closing of the Palæozoic and the highest New England surface represented at present by weathered peaks, all traces of the original level itself having doubtless vanished. Thus a late Trias (assuming the coincidence of the terms *cycle of erosion* and *period of sedimentation* such as Upper Cretaceous, Lower Cretaceous, Eocene, Oligocene, or Miocene age) appears to be the utmost we should assign to the Capoompeta surface. If, then, this level was a peneplain, as is suggested by the even heights of the highest central residuals, the removal of a whole mountain range was involved in its formation.*

The complete dismantlement of the Capoompeta level to-day, the excessive strength of the structures composing it, and the time involved in forming it by removal of the overlying mountains of indurated claystones and the granite itself, may be taken as proof that a very late-Permian peneplain continuously exposed after pronounced elevation† to sub-aërial agencies could not possibly preserve any trace of its original surface.

SUMMARY.

Four peneplains were developed in the granite area of northern New England, and successively raised by oscillatory movements to heights approximately of from 700 to 1,000, 600, 500, and 3,200‡ feet above sea-level. This was in the broad areas of central or maximum uplift only, the eastern and western margins of the horizontal or slightly differential uplifts being variably downfolded. The variable degree of plateau planation achieved by sub-aërial agencies in the successive periods of

* As evidenced by the post-Palæozoic folding movement, which can be shown to characterise the northern Permo-Carboniferous rocks while being characteristically absent from the Trias-Jura sediments.

† Say, 500 feet.

‡ By many the time occupied during the 3,200 feet uplift would be separated into at least four distinct cycles. Here, however, they are treated broadly under the name of the cañon period, from the great development of canons both before and after the basalt cycles.

gradation evidences the great discordances in age of the various cycles during which the peneplains were evolved. The migration of divides in northern New England is traceable to oscillations of the axes of uplift and the resultant imposition of varying slopes on the eastern and western limbs of the plateaus. Warping is evidenced for the surfaces of planation; generally considered, however, the disposition of the high level plains points to a wonderful evenness of movement since middle Mesozoic times.

The sequential forms induced in the older surfaces of erosion and newer areas of volcanism during the latest or cañon period evidence a great age for the chapter of activities embraced therein, and prove it to be referable to several distinct periods of surface modification, viz. :—

1. An original moderate uplift and cañoning of eastern and western slopes.
2. A minor period of volcanism succeeded by a magnificent basaltic demonstration, and accomplished by subsistence.
3. Pronounced erosion productive of down-like country in the weaker rocks.
4. A pronounced rise* accentuated easterly, accompanied by erosion, resulting in "valley in valley" structure, deep cañons, and a marked shifting of the divide westerly.

The basaltic cycle of New England is seen thus to fall within the space of time now known as the cañon period, and the relative instability of these basic rocks is clearly shown by a study of their characteristics. The stanniferous "leads" are also seen on physiographic grounds to belong to the cañon period.

The age of the granitic core, out of which the plateaus have, in the main, been chiselled, shows the insignificance of a *cycle*, in point of duration in time, as compared with that of the whole geological record. In addition the consideration of the various peneplains, and divisions of the cañon period, throws light on questions of geological age, since it is more than probable that cycles such as the Bolivia, Mole, Stannifer, and Cañon periods here described are the geographical equivalents of periods of sedimentation, such as the Upper Jurassic, Lower and Upper Cretaceous, and Tertiary.

* 3,000 feet approximately.

XXXI.—Analyses of Leucite Basalts, &c., and Olivine Basalts from New South Wales: by JOHN C. H. MINGAYE, F.I.C., F.C.S., Analyst, and H. P. WHITE, Assistant Analyst.

I.—LEUCITE BASALTS, &c.

I and II. Leucite Basalts from Byerock and El Capitan.

THESE Leucite Basalts have already been described by Messrs. David and Anderson.*

The analyses of these rocks quoted in that paper were by no means complete, and to some extent unreliable. Now that opportunity has arisen, fresh and complete analyses have been made on modern lines.

We are indebted to Mr. George W. Card, A.R.S.M., F.G.S., for the following petrological notes :—

III. Monchiquite.—Specimen 2257 in the Rock Collection of the Geological Survey.

" Nothing whatever is known of the history of this specimen, but it has always been regarded as coming from the locality from which J. M. Curran described a Leucite Basalt in 1891.† As the description there published does not, however, altogether tally with the specimen in question, the following notes on the latter may be advisable :—Under the microscope rather abundant phenocrysts of comparatively fresh olivine lie in a more or less automorphic groundmass of augite with some leucite, biotite, apatite and iron ores, and most probably nepheline, analcite, and a very little anorthite. The texture is that so generally seen in Monchiquites. There is an abundance of isotropic base of low refractive index, readily gelatinised when attacked by very dilute cold acid ; this is regarded as analcite, in accordance with modern views. Leucite occurs as rounded grains, sometimes showing indications of crystal form, and often containing the characteristic inclusions. Some of these crystals, which gelatinised with weak acid, must be regarded as pseudomorphs of analcite. Biotite is in very small quantity only. Augite is brown and pleochroic: it is for the most part automorphic, and is never phenocrystalline. Felspar has not been recognised with certainty, but the analysis indicates that a very small amount of anorthite may perhaps be present. A portion of the colourless base that possesses low double refraction may be regarded as nepheline, which, judging from the analysis, must be present."—(G.W.C.)

* "The Leucite Basalts of New South Wales." Rec. Geol. Survey N. S. Wales, 1889, I, Pt. 3, pp. 153–172.

† Proc. R. Soc. N. S. Wales, XXV, p. 210.

NOTES AND ANALYSES OF LEUCITE-BEARING ROCKS FROM NEW SOUTH WALES.

	I.	II.	III.
SiO_2	43·58	45·18	40·25
Al_2O_3	8·08	9·31	10·83
Fe_2O_3	5·00	6·31	5·30
FeO	5·77	4·08	8·00
MgO	12·91	10·77	12·53
CaO	8·88	8·56	9·64
Na_2O	·90	1·73	3·76
K_2O	5·99	6·93	1·48
H_2O (100° C.)	1·15	·55	·78
H_2O (100° C.+)	1·95	1·01	2·58
CO_2	·11	·17	1·14
TiO_2	4·64	4·36	2·74
ZrO_2	absent	absent	absent
P_2O_5	·62	·51	·73
SO_3	absent	absent	absent
Cl	trace	·05	·03
F	absent	absent	....
S (FeS_2)	absent	absent	absent
Cr_2O_3	·02	·02	·01
NiO, CoO	·08	absent	·06
MnO	·21	trace	·30
BaO	·32	·30	·18
SrO	trace	trace	trace
Li_2O	absent	absent	absent
V_2O_3	·03	·02	·04
CuO	·01	·01	absent
	100·25	99·87	100·38
Less Oxygen	....	·01	....
	100·25	99·86	100·38
Sp. Gravity of Rock	2·897	2·980	3·024

Analyses I and III, by H. P. White; II, by J. C. H. Mingaye.

I.—Leucite Basalt from El Capitan.

II.— „ „ Byerock.

III.—Monchiquite from Murrumburrah.

II.—OLIVINE BASALTS.

In the last part of the "Records of the Geological Survey," analyses were given of various Olivine Basalts in the Sydney District, and we are now able to furnish the chemical composition of six samples obtained from various country districts in New South Wales. The analyses have been conducted on material free from the weathered portions.

We are indebted to our Colleague, Mr. George W. Card, A.R.S.M., for the petrological notes on the basalts from Tweed River Heads, and Mount Tomah.

A. Olivine Basalt from Tweed River Heads.—" Fine-grained, non-porphyritic basalt. Under the microscope microlites of fresh labradorite and granules of olivine and augite lie in a deep brown glass."—(G.W.C.)

B. Olivine Basalt, Canoblas, near Orange.—*J. Milne Curran has described and furnished petrological notes on several slices of basalt for this district, and unfortunately it is not known from which site the specimen received for analysis was obtained.

C. Olivine Basalt from Mount Apsley, near Bathurst.—For petrological notes on this rock, we may refer to a paper by Mr. Clunies Ross, B.Sc., &c.—†" Basalts of Bathurst and Neighbouring Districts."

D. Olivine Basalt from Black Head, Ballina.—As no sections have so far been cut off this rock, no petrological notes are available.

E. Olivine Basalt from Gulgong.—J. Milne Curran has described two basalts from Gulgong.‡ The portion of rock held by the Department has so far not been cut.

F. Olivine Basalt from Mount Tomah.—" A black aphanitic Olivine Basalt tending to become doleritic in texture. Mineralogically it consists of a holocrystalline, somewhat fluidal groundmass of microlitic felspar, augite, and magnetite, in which are imbedded phenocrysts of olivine and tabular plagioclase. The phenocrystalline minerals are fresh. The plagioclase is at least basic as labradorite. A study of the analysis shows that there is insufficient silica to combine with the alkalis in the proportions required for the production of felspar; nepheline must, therefore, be present, although it has not yet been observed under the microscope. Chemically and mineralogically the Mount Tomah basalt agrees with those found intruding the Hawkesbury beds at various places, and it has undoubtedly emanated from the same magma basin."—(G.W.C.)

The fine powdered rocks on boiling for two minutes with dilute nitric acid, 1·40, gave, on filtering and evaporating the clear solution to dryness, much gelatinous silica.

* "Microscopic Structure of some Australian Rocks" Journ. R. Soc. N.S. Wales, 1901, XXV, p. 220.

† Journ. R. Soc. N. S. Wales for 1897, XXXI, pp. 304-306.

‡ Journ. R. Soc. N. S. Wales for 1891, XXV, p. 196.

ANALYSES OF OLIVINE-BASALT ROCKS FROM NEW SOUTH WALES.

	A.	B.	C.	D.	E.	F.
SiO_2	50·78	48·92	44·38	48·48	47·88	46·42
Al_2O_3	15·16	14·87	16·18	16·71	16·65	17·42
Fe_2O_3	2·36	3·99	1·94	5·93	2·45	3·70
FeO	10·01	7·44	8·54	5·96	7·08	7·45
MgO	4·43	5·73	10·30	4·19	7·91	6·61
CaO	6·46	7·26	9·20	7·02	9·25	8·56
Na_2O	3·54	3·42	2·55	3·38	2·64	3·61
K_2O	2·20	1·80	1·50	1·78	1·17	1·80
H_2O (100° C.)	·75	·82	·74	2·07	1·02	·34
H_2O (100° C. +)	1·32	1·56	1·99	1·44	1·38	1·52
CO_2	·01	·09	·04	·04	·04	·04
TiO_2	2·60	2·78	1·94	2·50	1·74	1·88
ZrO_2	absent	absent	absent	absent	min. trace	absent
P_2O_5	·34	·59	·31	·59	·36	·87
SO_3	·15	·08	·05	·10	·03	absent
Cl	·02	·02	·01	·07	·05	·05
F	absent	....	absent	....	....	?
S (FeS_2)	absent	absent	absent	absent	absent	absent
Cr_2O_3	absent	·01	·01	trace	·01	tr.(0·006%)
NiO, CoO	·05	·04	·04	·03	·05	·02
MnO	·14	·29	·26	·12	·22	·02
BaO	·05	·04	·07	·05	·10	·03
*SrO	trace	trace	trace	trace	trace	trace
†Li_2O	present	present	absent	present	absent	absent
V_2O_3	·02	·02	trace	·02	·01	·01
CuO	·01	·06	min. trace	·01	min. trace	....
	100·40	99·83	100·05	100·49	100·04	100·35
Less Oxygen	....	....	....	·01	·01	·01
	....	....	....	100·48	100·03	100·34
Sp. Gravity of Rock	2·795	2·865	2·927	2·761	2·858	2·905

A.—Olivine Basalt from Tweed River Heads.
B.— „ „ Canoblas Mountains, near Orange.
C.— „ „ Mount Apsley, near Bathurst.
D.— „ „ Black Head, Ballina, Richmond River.
E.— „ „ Gulgong.
F.— „ „ Mount Tomah.

Analyses A, B, D, and F, by J. C. H. Mingaye; C and E. by H. P. White.

* Less than 0·01%.

† Presence determined by spectroscope.

XXXII.—Notes on, and Analyses of the Mount Dyrring, Barraba, and Cowra Meteorites: by JOHN C. H. MINGAYE, F.I.C., F.C.S., Analyst.

[Plates LVII, LVIIA.]

I.—MOUNT DYRRING.

THIS meteorite, which originally weighed twenty-five pound, was found by an aboriginal at Mount Dyrring, eight miles north of Bridgman, in the Singleton District, New South Wales. It has been recorded by Mr. George W. Card, A.R.S.M., as consisting "of kernels of fresh pale green vitreous olivine of the size of a large Spanish nut, enveloped by a skin of magnetic iron in an advanced state of rust."*

Portions of the meteorite, weighing 900 grams, were broken up in a large diamond mortar, and then ground in a large agate mortar to pass through an 80-mesh sieve. (Sample I.)

An average taken from the above was finely ground, and enclosed in a glass-stoppered bottle, for the chemical analysis :—

On crushing, one small piece of metallic iron was obtained from the centre of a kernel, weighing ·026 grams.

No metal was left on the sieve, otherwise than the piece stated, or observed under the pestle on grinding the sample—the material, therefore, may be said to be practically free from metal.

Chemical Composition.—The powdered material is readily soluble in hot hydrochloric acid, with separation of granular silica, leaving a small black residue, consisting of chrome-iron ore.

The specific gravity of a mass weighing 12·230 grams was found to be 5 411, at a temperature of 23·8° C.

The analysis showed the following constituents to be present :—Silica, ferrous iron, ferric iron, alumina, magnesia, nickel oxide, cobalt oxide, chromium sesquioxide, carbon dioxide, sulphur trioxide, phosphoric anhydride, and gold, iridium, platinum, and palladium. No tin or vanadium were detected.

The gold and platinoid metals were detected by the following method, on two separate 400 grams (Sample I) :—

The material was fluxed with borax and sodium carbonate, litharge being added, and argol used as the reducing agent. It was then melted, and the resulting lead button scorified. To the clean lead 0·25 grams of pure silver were added, and the button cupelled in a small French bone-ash cupel.

* Records Geol. Survey N. S. Wales, 1903, VII, Pt. 3, p. 218, pl. 43.

The resulting silvery buttons in each case had the appearance of containing one or more of the platinoid metals.

They were then separately parted with pure nitric acid, leaving a small black residue (A).

The solution (B) was carefully poured off from the small black residue, well washed with distilled water, and the silver precipitated as chloride, washed and filtered. The clear solution was evaporated on the water bath, and on concentration gave a yellow colour, which on further concentration changed to a reddish colour. Again taken up with two drops of hydrochloric acid, diluted with distilled water and filtered from a trace of silver chloride. Solution of a light yellow colour.

(A.) The dark residue, insoluble in nitric acid, was ignited in a small porcelain crucible to a red heat. On cooling, gold was readily visible, there being also present a very minute amount of a black substance coating the gold, and probably iridium. The gold is estimated at 2·5 grains per ton.

(B.) To the yellow solution (free from silver) the following tests were applied :— On evaporating with ammonium chloride, yielded a dark-red crystalline precipitate, which I regard as ammonium-iridichloride. Potassium iodide gave a small black precipitate, which on settling and filtering the solution showed the characteristic pink tint obtained when traces of platinum are present.

It is stated that one part of platinum in 2,000,000 of liquid can be detected by this test.*

Stannous chloride gave a brownish precipitate, which on settling left the solution of a brownish-red colour.

Cyanide of mercury produced a very small yellowish-white, apparently gelatinous precipitate.

The litharge, reducing agent, and fluxes, were specially tested for the presence, or otherwise, of gold, platinum, &c.

Four separate lots, containing the same proportions of ingredients as used in the test for gold and platinoid metals, were fused in a crucible, and the resulting lead buttons scorified and cupelled. Small silver buttons in each case were obtained, the bullion being equal to from four to five grains per ton. On parting the buttons with dilute nitric acid, a minute trace of gold was obtained—only visible with a

* W. Crookes, "Select Methods of Chemical Analysis," p. 444.

strong magnifying glass, and considerably less than 0·5 grains per ton. The best flake litharge was used for the experiment, and the pure silver added, specially prepared and tested for minute traces of gold.

Chemical Analysis.

Moisture at 100° C.	·82
Water about 100° C.	3·89
Silica (SiO_2)	25·64
Alumina (Al_2O_3)	1·32
Ferric Oxide (Fe_2O_3)	29·90
Ferrous Oxide (FeO)	7·65
Manganous Oxide (MnO)	*trace
Lime (CaO)	·01
Magnesia (MgO)	27·90
Soda (Na_2O)	·14
Potash (K_2O)	*trace
Nickel Protoxide (NiO)	2·11
Cobalt Protoxide (CoO)	*trace
Chromium Sequioxide (Cr_2O_3)	·11
Titanic Oxide (TiO_2)	*trace
Sulphur Trioxide (SO_3)	·15
Carbon Dioxide (CO_2)	·13
Vanadium Oxide (V_2O_3)	absent
Copper Oxide (CuO)	†trace
Phosphoric Anhydride (P_2O_5)	·51
Chlorine (Cl)	·01
	100·29

No tin detected. Traces of gold, platinum, iridium, and palladium.

Mr. Card has supplied me with the following note :—

"It is evident from the analysis that the magnetic portion is not metallic, the oxidation being complete. From a study of the analysis, the original constitution of the meteorite can be approximately arrived at by assuming that the whole of the ferric oxide has resulted from the oxidation of nickel-iron—an assumption justified by the freshness of the only iron-bearing mineral present, viz., olivine, which shows no more than a staining of iron oxide upon surfaces of fracture. Water and carbonic anhydride are therefore rejected, and the following combinations made :—Iron and nickel in Fe_2O_3, and NiO to form iron-nickel alloy; FeO, MgO, and SiO_2 to form olivine; iron and sulphur to form troilite; iron, nickel, and phosphorus to form schreibersite. The resulting percentages are :—

Olivine	72
Nickel-iron	25
Schreibersite .. .. }	1
Troilite .. .. }	
Al_2O_3, Na_2O, &c.	2

* Less than 0·1 per cent.
† Copper 0·005.

> The formula for the olivine is readily found to be FeO, 7 MgO, 4 SiO_2, while the iron-nickel alloy must have contained about 95 parts of the former to 5 of the latter. A very few molecules of silica are available for the formation of a higher silicate. The analysis yields practically no lime; consequently the anorthite molecule cannot be present, and it remains uncertain in what particular combination the alumina and soda exist. The small amount of chromic oxide and chlorine suggests original chromite and lawrencite. The meteorite clearly belongs to the **Pallasites.**"

The mass is evidently fairly uniform in composition, an average from a second sample yielding :—Fe_2O_3 28·55 %, FeO 8·10 %.

The presence of platinum has been already recorded by the Author in meteoric iron, in 1898.*

Traces of platinum were detected in the Arispe Siderite, a meteorite found in the north-eastern portion of the State of Sonora, Mexico.†

From 23·9 grams of the Franceville meteorite, found in El Pasco County, Colorado, and described by H. L. Preston, a trace of platinum is reported by Mr. J. M. Davidson to have been detected.‡

Davidson also found in 606 grams of the Coahuila iron 0·014 grams of platinum, and 0·0015 grams of a black powder, insoluble in nitrohydrochloric acid. This residue on fusing with zinc, dissolved in that acid, and yielded with ammonium chloride a dark-red crystalline precipitate, which he regards as probably ammonium-iridi chloride.§

The presence of palladium in a meteorite is recorded by G. Trottavelli.‖

Prof. A. Liversidge records the occurrence of platinum and gold in the Boogaldi Meteorite, New South Wales.¶

II.—Barraba Meteorite.

(Plate LVIIa.)

The Barraba Meteorite was procured from the finder by Mr. H. Porter, of Hillgrove, who divided it, presenting one portion to this Department and retaining the other. The exact locality has not transpired. It was rumoured that other fragments were in existence.

---

* Ann. Rept. Dept. Mines N. S. Wales for 1898, p. 21.

† Procs. Rochester Acad. Sci., 1902, IV, p. 86.

‡ Procs. Rochester Acad. Sci., 1902, IV, p. 77.

§ Am. Journ. Sci., 1899, p. 44.

‖ *Vide* Journ. Chem. Soc., Abstracts, 1891, p. 533.

¶ Journ. R. Soc. N. S. Wales, 1902, XXXVI, p. 344.

An average sample taken by boring the slice sent for analysis, eliminating the crust coating the outer surface of the meteorite, yielded as follows :—

Chemical Composition.

	I.	II.
Fe	93·47	93·52
Ni	5·55	5·53
Co	·52	·50
Cu	·01	not detd.
Sn	·02	not detd.
Pt. and Ir.	traces	traces
P	·27	·24
Mn	*trace	*trace
S	absent	absent
Si	·01	·01
C	·03	·02
	99·88	99·82

Sp. Gravity of piece weighing 65·8520 grams—7·761 at 22·7° C.

On dissolving a portion of the borings taken for analysis in warm hydrochloric acid (1 : 3), a small residue was left, consisting of bright metallic particles, and a black carbonaceous residue, which did not dissolve on long continued treatment with the acid.

A solid piece weighing 23·362 grams was treated with warm hydrochloric (1 : 3), and it was observed, as the metal dissolved, that bright metallic particles shred from the mass and settled at the bottom of the beaker. The solution was poured off, and the residue again treated for some time with warm acid, which had little or no action—the mass still retaining its metallic lustre.

The latter were readily separated from the carbon and examined under the microscope, when they were seen to consist of a mixture of needles or laths, some of which are small, others elongated; also some flat plates showing a series of finely-etched parallel lines, colour steel-grey, magnetic. (Plate LVII, fig. 2.)

A columnar or corrugated structure is also seen on several of the plates (Plate LVII, fig. 1)—similar to those described and figured by Davidson in Kamacite from the Welland Iron.†

Weight of residue insoluble in hydrochloric acid (1 : 3), ·2162 grams; equal to ·92 per cent.

A further piece of the meteorite, weighing 30·624 grams, was dissolved in hydrochloric acid (1 : 3), as in the former experiment, and the bright metallic particles after separation from the carbon weighed—yielded ·2548 grams, equal to ·83 per cent.

* Less then 0·01%. The absence of chlorine proved. Traces of platinum and iridium.

† Procs. Rochester Acad. Sci., 1891, I, p. 172, pl. 11

The specific gravity of the material was found to be 6·339, at a temperature of 20° C. The particles are readily magnetic, with the exception of one small lath of a steel-grey colour, weighing ·0022 grams, which has been retained for further examination. It is very insoluble in hydrochloric acid (1 : 3), also in nitric acid (1 : 3), but dissolves readily in nitro-muriatic acid to a clean solution of a yellow colour. 0·2 grams of the material first prepared was taken for analysis, and found to have the following composition :—

Chemical Composition.

Fe	62·27
Ni	21·69
Co	·46
Sn	trace
P	15·53
	99·95

A determination made on 0·1 grams from the second prepared material yielded :—

Chemical Composition.

Fe	64·12
Ni, Co	24·60 (by difference)
P	11·28
	100·00

It is very evident, from the wide differences in the analyses, that the material is not uniform in composition, and it consists largely of a mixture of schreibersite and rhabdite (phosphides of iron and nickel), together with some kamacite. The carbonaceous residue separated from the steel-grey material by washing, and obtaining the light and heavier portions, was filtered, the filter dried and burnt. The residue left on burning off the carbon, also 0·1 grams of the steel-grey material, and 0·025 grains of pure silver were wrapped in a piece of assay sheet-lead and cupelled off on a small French cupel. On parting the resulting button with nitric acid, a small quantity of a black residue was left; insoluble in nitro-hydrochloric acid, and from the microscopic appearance evidently iridium.* The silver in the solution was precipitated as chloride, filtered, and the clear solution evaporated down to dryness on a water-bath. On concentration, of a light-yellow colour, readily giving the characteristic reactions for platinum, by the stannous chloride and potassium iodide tests. Although the residue was carefully examined for gold, its presence was not noted.

It is considered by Mr. Card, that the meteorite appears to be identical with the Bingera Iron,* which is a hexahedrite, of the Chesterville Group—a very rare type. The find is therefore of exceptional interest.

* Ann. K.K. Naturh. Hofmus. Wien. 1896, X, heftes 3 and 4, pp. 295–297 (with figure).
Rec. Geol. Survey N. S. Wales, 1897, V, p. 52 (with figure).
A. Liversidge, Minerals of N. S. Wales, pp. 218–220 (with figures).

III.—THE COWRA METEORITE.

The Cowra Meteorite originally weighed 12½ lb., and is exhibited in the Mining and Geological Museum.* It is stated to have been discovered by Mr. O'Shaughnessy, who found it firmly embedded in slate rock, at the summit of Battery Mountain, at the junction of the Burrowa and Lachlan Rivers, a few miles east of Cowra.

Dr. Brezina classes it as a sub group of group 43†—that is, with the finest lines of the Octahedrites—a rare variety. The specific gravity of a piece weighing 54·4862 grams was found to be 7·805, at a temperature of 21·4°C.

An average taken by boring a slice in several places, yielded on analysis as follows:—

Chemical Composition.

	I	II
Fe	85·31	85·22
Ni	13·18	13·28
Co	1·04	1·00
Cu	·02	..
Sn	trace	..
Mn	do	..
P	·22	·23
S	·01	..
Si	·01	..
C	·02	·03
	99·81	99·76

Pt and Ir were detected in the Meteorite; also in the fine dust obtained by sawing the slice off the mass.

By dissolving 34·540 grams of the Meteorite in hydrochloric acid (1 : 3) a residue consisting of bright metallic particles of a steel-grey colour, and a very small quantity of a black powder (carbon) was left. The metallic portion is magnetic, and only soluble in nitric acid (1 : 3) on long-continued boiling. The carbon was separated from the metallic particles by lixiviation, and the latter weighed. Weight 0·5638 grams, equal to 1·63 per cent.

0·4 grams taken for analysis gave the following composition of the material:—

Chemical Composition.

Fe	51·45
Ni	34·10
Co	trace
P	13·09
Insoluble in acid	·85
	99·49

Under the microscope the material consists of bright grains of a steel-grey colour. No laths, or needles, as shown in the insoluble residue in the Barraba Meteorite were observed. The material appears to consist entirely of Schreibersite.

I am indebted to Mr. Thomas Whitelegge, of the Australian Museum, through the courtesy of Mr. Robert Etheridge, Curator, for the micro-photographs illustrating this paper.

* Records Geol. Surv. N. S. Wales, 1899, I, Pt. II, p. 51, pl. 7.
† Brezina, Ann. K.K. Naturhist. Hofmus. Wein, 1895, X, hefte 3–4, p. 269.
‡ T. Cooksey, Catalogue and Bibliography of Aust. Meteorites, Rec. Aust. Mus., III, No. 3.

XXXIII.—Notes and Analysis of the Mt. Browne Meteorite: by HAROLD P. WHITE, Assistant Analyst.

"THIS meteorite fell at Mt. Browne, New South Wales, at about 9·30 a.m. on 17th July, 1902. Just before the fall an explosion had been heard, immediately after which a hut caught fire. A whizzing sound followed, and the meteorite struck the ground some distance away from the hut, raising a cloud of dust. It was picked up by W. Jordan a few minutes after its fall, and was still warm. A black skin of fused material envelopes the meteorite, and the usual 'thumb-marks' are visible. The interior is fine-grained, and light-grey in colour—probably exceptionally so for a meteorite. It is stony in texture, and shows numerous little glancing faces of metallic iron of a pale brassy appearance. The present weight is 25¼ lb., and it is believed that at least one pound was broken off by the finders."*

Throughout the meteorite there are numerous small patches of a yellowish material, but I could not obtain sufficient of this to enable an analysis to be made. A few specks were placed on a glass slide and treated with a drop of warm dilute hydrochloric acid, and examined under the microscope; the colour gradually disappeared. The quantity is very small, and the substance seems to merely stain the silicate.

This aerolite breaks easily under the hammer. Some of the pieces obtained by chiselling could be reduced in size by rubbing with the fingers when, frequently, thin slabs of material broke off; these could be easily broken with the fingers into smaller pieces. But occasionally some of these smaller portions required a fairly hard blow with the agate pestle before breaking up.

An average sample, obtained from numerous small fragments, was carefully broken in a steel mortar, then ground in an agate mortar. The crushed material was sorted with a magnet. Both portions—magnetic and non-magnetic—were weighed, and the calculated proportions taken for an analysis of the meteorite as a whole. It was found impossible to obtain the metal free from mineral matter. What seemed particles of clean metal, the microscope revealed to be always metal traversed by thin veins or small masses of silicate. Fusion with caustic soda failed to completely remove the mineral, and treatment with cold dilute sulphuric acid and hydrofluoric acid cleaned the surface of the silicate, which then had the appearance of white veins or grains on a dark ground mass of metal.

The iron is not uniformly distributed—thus, 40 grms. of meteorite yielded 19·68 per cent. of metal, whilst another portion weighing 120·4 grms. yielded 34·22 per cent. of metal. The unequal distribution of iron in this class of meteorites has

* G. W. Card, Records Geol. Survey N. S. Wales, 1903, VII, Pt. 3, p. 218.

been pointed out by other observers. In his description of the "Llano Del Inca" stony meteorite, E. E. Howell states, "one piece which we have polished seems to unite the two extremes, one side containing a large amount of iron, while the other side, half an inch distant, contains only a few particles."*

The size of these metallic grains varies considerably: one, the largest noticed, was fairly round, and measured almost five millimetres in diameter; many others had a diameter of two or one millimetres; while a large number were like coarse or fine dust. Troilite is present in considerable quantity, particularly in the stony portion. Owing to the difficulty in finding particles of silicate free from troilite, attempts to separate the silicates, by dense solutions, were only partially successful.

Before analysis the sample was dried over sulphuric acid.

Analysis of the meteorite as a whole.

SiO_2	34·81
Al_2O_3	2·27
Fe	28·84
Ni	1·78
Co	·26
Cu	mere trace
Sn, Sb	absent
MgO	23·35
CaO	2·24
Na_2O	1·17
K_2O	·24
Li_2O	absent
MnO	mere trace
Cr_2O_3	·02
V_2O_3	mere trace
TiO_2	mere trace
BaO, SrO	absent
ZrO_2	absent
Cl	absent
P	·11
S	2·02
C	·11
O by diff.	2·78
	100·00.

The oxygen is equivalent to 12·51 per cent. of FeO, but there is about 0·40 per cent. of Fe_2O_3 present, which quantity is calculated from the amount of Fe_2O_3 soluble in acid.

This meteorite contains a very small quantity of some hydrocarbon, the presence of which was detected by heating some of the sample in a glass tube, closed at one end—when it was noticed that white fumes were evolved; these had the odour of charred organic matter, and on the sides of the tube could be seen a few small drops of some liquid, which further heating blackened. The non-metallic portion

* Rochester Academy of Science, 1890.

has a soapy feel, and when finely ground it is readily acted on by acids, even when the acid is very dilute. Cold—5 per cent. hydrochloric acid dissolves out silica and magnesia. Boiling—5 per cent. acetic acid also removes fair quantities of silica and magnesia. If some of the mineral is shaken with cold dilute acid for a few minutes magnesia can readily be detected in solution.

One gram of the finely-ground stony portion was treated with warm 5 per cent. hydrochloric acid for two hours; the solution was filtered off and evaporated on the water-bath, when gelatinisation took place. The silica obtained weighed 0·1386 grm., while the magnesia found in solution weighed 0·1786 grm. The total quantity of mineral matter soluble by this treatment was found to equal 48·63 per cent.

Analysis of the portions soluble in warm 5 per cent. hydrochloric acid :—

(Calculated to 100 parts.)

SiO_2	28·81
Fe_2O_3	1·03
FeO	17·09
FeS	14·40
CaO	·76
MgO	37·12
Al_2O_3, P, and undetermined	·79
	100·00

Analysis of the portion insoluble in acid :—

SiO_2	54·38
Fe_2O_3	absent
FeO	8·73
Al_2O_3	6·58
Cr_2O_3	·50
CaO	3·70
MgO	24·16
Na_2O	1·97
K_2O	·26
	100·28

The stony portion is chiefly enstatite, with an easily soluble olivine, the exact nature of which it is difficult to determine, " and a little felspar."

Mr. G. W. Card, A.R.S.M., F.G.S., to whom my best thanks are due for assistance kindly rendered, informs me that " after many attempts the lapidary succeeded in making a coherent slide, it is too thick to be of much use, however the coloured pyroxenes are not noticeable, so that hypersthene and augite may be neglected. I think our previous opinion was that the bulk of the silicate was enstatite, and this view is strengthened by the optical and mechanical tests."

XXXIV.—Sub-Reniform-ovate Leaves of *Glossopteris*, with further remarks on the attachment of its Leaves: by R. ETHERIDGE, Junr., Curator of the Australian Museum, Sydney.

[Plates LVIII, LIX.]

A well-marked horizon occurs in our Upper Coal-Measures at the foot of Mount Kembla, Illawarra District, distinguished by the presence of large ovate leaves or fronds of *Glossopteris*, with sub-reniform bases. These were collected by Mr. Charles Cullen, Collector to the Geological Survey. I have not at hand all the works bearing on Glossopteris Floras, but so far as I am aware, fronds displaying this character have not heretofore been figured, certainly not from any portion of the Australian Permo-Carboniferous Coal-Measures.

I am thoroughly in agreement with some Palæbotanists, for instance, Mr. A. C. Seward,* "in endeavouring to avoid the dangerous and unscientific practice of needlessly multiplying specific names," when diversity of form amongst such fronds as those of *Glossopteris*, possibly in many cases, only represents a difference in age. It seems to me, however, that so unusual a character as that exhibited by the bases of the Mount Kembla fronds merits special distinction.

The average size of these fronds is four and a quarter inches long, by three inches wide, very obtusely pointed above, and broadly ovate below, but sub-reniform in the middle line. The mid-rib is thick and strong, extending almost to the upper margin, striated but not grooved, terminating below in a strong foot-stalk. The base is bi-auriculate or sub-reniform, the auricles distinctly separated from the leaf-stalk, and forming two pronounced equal lobes, the former uniting with the frond in the semi-circular notch between the latter. The net-venation is coarse, the meshes oblong-polygonal with both square and angular ends, largest near the mid rib, becoming narrower and still more oblong-polygonal towards the margins; in the lower portions of the fronds the veins issue almost at a right-angle, but towards the middle of the fronds they proceeds outward at an angle of about 60°.

The outline of these fronds is quite distinct from that of any *Glossopteris* foliage known from our Coal-Measures, the relative proportions of length and breadth being very distinctive. The net-venation agrees better with that of *G. parallela*, Feistm. than with any other of our forms, but the meshes are larger. The largest *Glossopteris* fronds in our rocks are those of *G. ampla*, Dana; these are to some extent ovate, but are non-auriculate, with a highly developed leaf-stalk, and a

* Quart. Journ. Geol. Soc., 1897, LIII, p317.

very marked venation of their own, particularly the fine and long meshes of the peripheral halves of each frond. At first sight *G. cordata*, Dana,* might be taken to have some relation to these fronds. In Dana's figure the basal margin does appear to be incurved on each side the mid-rib, but a little consideration will convince the observer that this is simply a fractured edge. There is no indication of a branched mid-rib, the branches passing into the lobes as in *Belemnopteris*, Feistm.

These fronds do not, strictly speaking, fall within the general definition of those of *Glossopteris*, in that they do not gradually contract, or run out towards the base—take for instance one of the latest definitions, that of Prof. R. Zeiller.† The fronds are of less width across the immediate base than they are over the middle, it is true, but there is not the gradual attenuation usually met with.

It is proposed to call these fronds *Glossopteris nephroeidicus*.‡

I notice that Prof. Zeiller describes the fronds of *Glossopteris* as attached only to a rhizome, *i.e.*, an elongated, more or less horizontal subterranean stem, and makes no reference to my description of fronds forming a clump at the end of a stem or caudex bearing leaf-scars.§ His interpretation of the nature of *Vertebraria* as the rhizome of certain *Glossopteris* fronds appears to be soundly established.‖ Subsequently Mr. R. D. Oldham published a description and figure of *Glossopteris* fronds forming a clump, also said to be attached to a *Vertebraria* rhizome,¶ but in the latter case the *Vertebraria* nature of the attachment is by no means so clear as in those specimens from South Africa figured by Prof. Zeiller. There is also this manifest difference between these respective illustrations, that whilst the South African fronds are placed singly along the rhizome, as one would expect, the fronds on the Indian specimen present exactly the same arrangement as in the New South Wales plant.

In a more recently published paper,** Mr. N. Arber appears to imply doubt of the accuracy of my interpretation of the Mudgee specimen, and says :—" In 1894 Mr. R. Etheridge, jun., described some Australian specimens in which almost complete fronds of *Glossopteris* were preserved in organic continuity with a structure which he regarded as a rhizome. Judging by his figures, this rhizome is quite unlike *Vertebraria australis*. Possibly it was preserved in a different manner, as an external impression, without the wedge-like segments (as seen in transverse

* Wilkes U. S. Explor. Exped., X (Geol.), 1849, t. 13, p. 5.

† Éléments de Pal.-Bot., 1900, p. 113.

‡ Νεφροειδής, resembling a kidney.

§ Proc. Linn. Soc. N. S. Wales, 1894, IX (2), p. 223.

‖ Bull. Soc. Géol. France, 1896, XXIV (3), No. 5, t. 15, f. 7-9a ; Plantes Foss. Lower Gondwanas (Pal. Ind., II, n.s.), Pt. 1, 1902, pp. 17, 20.

¶ Rec. Geol. Survey India, 1897, XXX, Pt. 1, p. 45, t. 3.

** Quart. Journ. Geol. Soc., 1902, LVIII, p. 8.

section) which are so characteristic of *Vertebraria*." I beg to suggest, with all diffidence, that Mr. Arber should be a little more careful not to support his own views by mistaking those of others. In the first place, I did not describe "specimens" in organic continuity with any other object, but one specimen. In the second place, Mr. Arber mis-states me when he says "with a structure which he regarded as a rhizome." Nowhere in my paper did I refer to a rhizome in connection with the Mudgee specimen, but I was very careful throughout, rightly or wrongly to speak of a caudex, *i.e.*, a trunk or stem as opposed to a rhizome, with or without a terminal tuft of fronds. Furthermore, I stated there was reason to believe the fronds were arranged in a spiral manner on the stem, and the leaf-scars figured support this view. "Possibly," says Mr. Arber, "it was preserved in a different manner, as an external impression." If Mr. Arber will look at the figure a little more carefully, he will see that the latter represents an exterior impression, showing the leaf-scars, but, as I said, "with the whole of the organic matter removed," and "leaving only the impression of the parts on the slab of fine sandstone forming the matrix." Again, Mr. Arber remarked, "without the preservation of the wedge-like segments (as seen in transverse section) which are so characteristic of *Vertebraria*." There is no "possibly" in the question whatever, and had any structure been preserved in the transverse section of the stem-core, such would have been described and figured.

Prof. Zeiller's figures of the attachment of *Glossopteris* fronds to a *Vertebraria* rhizome, and for all I can say to the contrary, so no doubt is the specimen mentioned by Mr. Arber forming a part of the Clarke Collection,* are just as conclusive as the fact that those figured by me are not so attached. It is somewhat remarkable that Prof. Zeiller mentions an example of *Vertebraria* from near Johannesburg, "portant à son sommet un bouquet de grandes fronds de *Gloss. indica*."†

In Mr. Oldham's paper two entirely different sets of organisms are described—the attached *Glossopteris* fronds, and *Vertebraria* specimens—the two from different localities be it remembered. The resemblance between the arrangement of the clump of fronds in Mr. Oldham's figure and that in mine of the Mudgee plant is most marked. That the fragment affording attachment to the fronds in the Indian specimen, and termed "a root-stalk," is of the nature of *Vertebraria*, there is very little evidence either in the description or figure to show. I by no means deny that it is not of this nature, not having seen the specimen, but it appears to require confirmation. All Mr. Oldham says is —"the small rhizome shows indistinctly, it is true, but recognisably, the median ridge and transverse partitions of *Vertebraria*"; they certainly are very indistinct.

* Quart. Journ. Geol. Soc., 1902, LVIII, p. 8.

† Plantes Foss. Lower Gondwanas (Pal. Ind., II, n.s.), Pt. 1, 1902, p. 17.

I now figure a small specimen from the same horizon as the sub-reniform ovate fronds, consisting of four small fronds, each exhibiting a mid-rib and net venation, from three-quarters to one inch long, arranged in a radiate manner around a central point. At the latter there is a slight protuberance without structure, but differing in colour from the surrounding matrix. The fronds most certainly radiate from this point, although apparently pressed from above downwards, but whether forming a clump, whether in a verticil, or spirally placed, it is impossible to ascertain in the absence of a longitudinal view.

I do not profess to explain these anomalies—why in the Transvaal beds *Glossopteris* fronds should on the one hand be found attached singly along a rhizome, and on the other forming a clump or " bouquet " at the end of one; why in New South Wales similar fronds should occur in the latter condition, and again in like arrangement at the end of a stem exhibiting leaf-scars; and, lastly, why, in India, fronds should be met with displaying the frond growth of one of the Transvaal and Australian conditions.

XXXV.—Notes on some new species of Palæozoic Brachiopoda from New South Wales: by W. S. DUN, Palæontologist.

[Plates LX, LXI.]

1. *Meristina (?) australis*, sp. nov.

(Plate LXI, figs. 3*a–e*.)

SHELL meristelliform, circular, smooth. Pedicle valve strongly convex, beak strongly incurved, not prominent, almost touching brachial valve, and hiding delthyrium and foramen. Umbonal region convex; lower third of central area occupied by a broad shallow sinus which towards the margin shows elements of folding.

Brachial valve more convex than the pedicle and very strongly arched in the central region, but showing no differentiation into a median fold.

Margin strongly sinuate.

The internal structure is unfortunately practically unknown. The subject of Plate LXI, fig. 3*e*, shows a shell with portion of the brachial valve removed. The two elevated portions disclosed represent, to a certain extent, the replacement of the spiral cones, but give no information of value to classification. The degree of crystallisation of the limestone has entirely destroyed all traces of loop structure.

Dimensions of largest specimen :—

Length	26 mm.
Width	29 „
Thickness	19 „

Considerable doubt must exist, owing to the absence of evidence of internal structure, as to the correct generic position of this form. The general external appearance at once places it in either *Merista*,* *Meristella*,† or *Meristina* (*Whitfieldia*),‡ forms of the greatest similarity outwardly, and separable only when the internal structure, more particularly of the loop and hinge-plate, are known. The safest course appears to be to refer these shells provisionally to the genus *Meristina*, Hall, and in so doing, one is at once struck with the very strong outward resemblance to *M. tumida*, Dalman,§ a form occurring abundantly in the Silurian of Europe.

From *M. tumida* it can only, in the case of non-mature forms, be separated by its more circular outline and the relatively greater convexity of the brachial valve; in aged forms the plication of the sinal region is characteristic.

M.(?) *australis* may also be compared with Barrande's *Atrypa linguata*, v. Buch,‖ and *Merista Herculea*, Barr.,¶ from étage E, than which it is more circular.

De Koninck has recorded** the occurrence of *Meristella tumida* (?) from the Silurian of Slaughter-house Creek, Delegate River, but judging from his brief note it appears more probable that the Delegate specimen is co-specific with an undescribed form which occurs in considerable abundance in the Yass beds.

Locality :—Abundant in a drab-coloured limestone near Molong.
Horizon :—Silurian.
Collector :—C. Cullen.

2. *Cyrtina wellingtonensis*, sp. nov.

(Plate LXI, figs. 2–2*c*.)

Shell cyrtiniform, pyramidal, pedicle valve high, area very much developed, the height more than half the width of the cardinal margin. Area but slightly concave, and beak of pedicle valve overhanging slightly, surface marked with transverse lines. Delthyrium long and narrow, deltidial covering convex, imperfect in all the specimens in the collection, so that the position and form of the foramen cannot be determined.

* Hall and Clarke, Pal. N. York, 1894, VIII, Pt. 2, p. 65, t. 41, f. 1–25.
† Hall and Clarke, Pal. N. York, p. 70, t. 42, f. 1–12.
‡ Hall and Clarke, Pal. N. York, p. 73, t. 43 and 44.
§ Davidson, Mon. Sil. Brachiopoda, 1866, p. 109, t. 11, f. 1–13; Hall and Clarke, *op. cit.*, p. 65, t. 41, f. 4, 24, 25; Barrande, Syst. Sil., V, t. 11.
‖ Syst. Sil. Bohême, 1879, V, t. 14, f. II.
¶ Syst. Sil. Bohême, 1879, V, t. 13, f. I.
** Foss. Pal. N. Galles Sud, Pt. 1, 1876, p. 36; English Trans., p. 28.

Cardinal angles rounded in some specimens, more acute in others.

The surface is ornamented with undulating folds on either side of a median sinus, the first faint, the others distinct and well marked towards the margin. In the variety with rounded cardinal angles the folds are well rounded, but in the sharper eared forms these take on a more accentuated condition; well marked laminar growth lines are present.

The brachial valve is almost flat, and but very slightly convex. The median fold is developed to the same extent as the sinus of the pedicle valve, and the folds or ribs, three in number, correspond closely to those of the opposite valve. Hinge area very small, beak not prominent and projecting very slightly.

The internal structure is but imperfectly known. In Plate LXI, fig. 2*a*., the fracture of one of the lateral expansions shows remains of one of the spiral arm supports situated entirely within the plane of the pedicle valve and directed upwards. In the same specimen, a certain portion of the deltidial covering is preserved, and owing to the open condition of the upper portion of the delthyrium, the well-marked median septum can be seen.

Dimensions.

Length (pedicle valve)	10.5 mm.
Width	11 ,,
Height of cardinal area	7 ,,

Observations.—There is a very strong resemblance between the specimen represented in Plate LXI, fig. 2*b*, and that of the pedicle valve of *C. acutirostris*, Shumard,* from the Choteau Limestone, but comparison of the brachial valves shows that that species has a far more auriculate outline than *C. wellingtonensis*.

The species cannot be confused with the European *C. heteroclita*, Defrance, and *Demartii*, Bouchard, as figured by Davidson.†

Locality :—Uncommon in dark limestone, Wellington Caves.
Horizon :—Silurian.
Collector :—C. Cullen.

3.—*Spirifera Pittmani*, sp. nov.

(Plate LXI, figs. 4, 4*a*–*b*.)

An ostiolate Spirifer.

Pedicle valve strongly gibbous; hinge-line relatively short; deep sinus without any plications, and bounded on either side by 8–10 well-marked ribs, strongly marked in the median, but faint towards the cardinal extremities. In youth the shell shows the width greater than the length, but in aged stages this relation of dimensions is changed, and the pedicle valve is sub-circular in outline.

* Hall and Clarke, Pal. N. York, 1894, VIII, Pt. 2, t. 28, f. 38, 41
† Brit. Foss. Brach. (Devonian), III, 1864, t. 9, f. 1–17.

In the brachial valve the fold is well developed and smooth, the ribs are of the same character as those of the pedicle valve.

Of the internal characters nothing is known beyond the fact that the dental plates are strongly developed.

Observations.—There can be little doubt that this *Spirifera* falls within Hall and Clarke's Class V (*Ostiolati*),* and also that it is very closely related to the well-known Devonian *S. ostiolata*, Schlotheim (= *S. brevicostata*, Valenciennes).† Sir Frederick McCoy described‡ a *Spirifera* from the Middle Devonian limestones of Buchan and Bindi, North Gippsland, which he referred to the European species. As compared with the Victorian, as well as the European forms, *S. Pittmani* presents a different appearance in the greater length of the adult form and smaller number of ribs.

This type of *Spirifer* is very common in the Devonian beds of America. The protean form *S. granulosus*, Conrad, from the Hamilton Group, which also comprises, according to Schuchert,§ *S. Oweni*, Hall,‖ shows considerable resemblance to *S. Pittmani*, except in the fact the ribs are more numerous and less accentuated in the American form.

Locality.—In limestone, The Troffs, one mile east of Portion 13, Parish Gillenbine, County Cunningham; on boundary between Parishes Gobondery and Gillenbine.

Formation.—Devonian.

Collector.—E. F. Pittman, A.R.S.M., Government Geologist.

4. *Chonetes Culleni*, sp. nov.

(Plate LXI, figs. 1, 1*a*.)

Shell of medium size, pedicle valve strongly arched, ornamented with well-marked ridges occasionally bifurcating round the margin, from fifty to fifty-four in number. Hinge-line the greatest width of the shell, width about one-quarter greater than the length. The cardinal tubular spines are well developed, five on either side of the beak, straight, and directed towards the cardinal angles at 45°. Well-marked area in the pedicle valve.

Brachial valve concave, area almost linear; in fig. 1*a* the stump of the cardinal process is seen. There is a well-marked ridge extending from beneath this process for about three-quarters the length of the valve. The upper portion of the

* Pal. N. York, 1894, VIII, Pt. 2, p. 28; characterised by the fact that the median fold and sinus are without plications—cf. figures of *S. audaculus*, Conrad, in Hall and Clarke, *op. cit.*, t. 24.

† For references and figures see Davidson, Brit. Foss. Brachiopoda (Devonian), III, 1864, p. 28, t. 8, f. 4, 5; Scupin, Spiriferen Deutschland, Pal. Abhandl., 1900, IV (n.f.), heft. 3, p. 30.

‡ Proc. Pal. Vict., 1876, Dec. IV, p. 16, t. 35, f. 2, a–b.

§ Bull. U.S. Geol. Survey, 1897, No. 87, p. 391 (for synonymy).

‖ Hall, Pal. N. York V, t. 29, f. 1–8, especially figs. 1–6.

brachial ridges are prominent and but slightly curved towards the central septal ridge. There is no papillose appearance preserved in the outer pallial region, but the external ribbed condition is strongly presented on the inner surface.

Observations.—Chonetes Culleni falls into the Section Striatæ of De Koninck's subdivision of the genus into sections.* This group is characterised by the possession of smooth radiating ridges, more than thirty and less than one hundred in number. To this section Waagen has added the Comatæ of De Koninck, which possess more than a hundred ribs—as he points out, a rather unnatural subdivision†. Waagen's suggestion is adopted by Hall and Clarke.‡

There is no near alliance between this species and any of those figured by Davidson in his "Monograph of the British Fossil Brachiopoda." Compared with the species figured by Hall and Clarke,§ *C. Culleni* has considerable resemblance to *C. Yandellana*, Hall, ‖from the Corniferous Limestone, but from that our species differs in the elevation of the shell being much greater; there also seems, judging by the figures, to be a difference in size. There is also considerable resemblance to *C. illinoisensis*, Hall,¶ from the Burlington, from which it also may be distinguished by the depth of shell, coarser striation, and greater size. In the form of the ears there is a great resemblance to *C. pusilla*, Hall,** and *C. vicinus*, Castlenau (= *deflecta*, Hall††), both from the Hamilton Formation.

Of the forms figured by Barrande there are only two with which comparison need be made. There is considerable agreement in outline with *C. embryo*, Barr.,‡‡ but in no other respect is there similarity, the striations being much finer and more numerous, and there being only two spines in the Bohemian species. *C. bohemicus*, Barr.,§§ is relatively broader and the ornamentation differs, being finer and exhibiting puckering at a little distance from the margin.

McCoy has described *C. australis* from the Middle Devonian of Lucknow and Buchan, Victoria, ‖‖ which he states is closely allied to *C. sarcinulata*, Schlotheim of the Rhenish Devonian. Judging by McCoy's figures, our species may be readily distinguished by the higher convexity of the pedicle valve and coarser and less frequent ribbing; there is also a less marked flattening towards the angles in the New South Wales species. Mr. F. Chapman, A.L.S., of the National Museum, Melbourne, who has kindly compared a specimen of *C. Culleni* with McCoy's type,

* Mon. des genres Productus et Chonetes, 1847, p. 183.
† Salt Range Fossils, Pal. Indica, Ser. XIII, 1884, I, p. 615.
‡ Pal. N. York, 1892, VIII, Pt. 1, p. 306.
§ *Op. cit.*, 1892, VIII, Pt. 1, t. 16, f. 14.
‖ Hall, Pal. N. York, 1867, IV, t. 20, f. 4.
¶ Hall, *op. cit.*, t. 22, f. 14-15.
** Hall, *op. cit.*, t. 21, f. 6.
†† Hall, *op. cit.*, t. 21, f. 7, 8.
‡‡ Syst. Sil. Bohêmę, 1879, V, t. 46, vii, f. 1, 2, 3.
§§ *Op. cit.*, t. 46, f. ii.
‖‖ Prod. Pal. Vict., 1876, Dec. 4, p. 17, t. 35, f. 3-5.

informs me that *Culleni* may be distinguished readily by its greater length, more tumid umbonal region in the pedicle valve, which flattens towards the anterior margin, tendency towards bifurcation displayed by the ribs, the longer cardinal spines, and greater size.

From *C. sarcinulata* as figured by Tschernyschew,* it also differs mainly in the depth of the pedicle valve.

This form also is clearly distinguishable from the Victorian Silurian forms described by Mr. F. Chapman as *C. melbournensis*, *robusta*, and *Cresswelli*.†

De Koninck has recorded *C. striatella*, Dalman, from Quedong, and *C. coronata*, Conrad, and *hardrensis*, Phillips, from Kempsey and Yass and Kempsey respectively.‡ He does not, however, figure any of the specimens. There appears to be no possibility of confusing *C. Culleni* with De Koninck's recorded *striatella*, nor yet with *C. hardrensis*, assuming that he made correct references to those species.

Locality.—In a bluish limestone, Portion 65, Parish Taemas, County Cowley.

Horizon.—Devonian.

Collector.—C. Cullen.

5. *Spirifera Davidis*, sp. nov.

(Plate LX, fig. 1, 1*a–f*.)

Valves much longer than broad; pedicle valve very convex, with a well developed broad median sinus, in some forms rather shallow; apparently without any folds or ridges either in sinus or on the shoulders; surface traversed by from ten to twelve depressed ridges on either side of the sinus, very indistinct on aged individuals. The median region is continued into a well-marked lingual extension at the anterior margin; wings blunt, beak well developed and closely overhanging the cardinal area. Adductor and diductor scars situated in a well-marked depression; vascular markings and radial furrows corresponding to the external ridges are visible on internal casts.

The brachial valve is much less convex than the pedicle; the fold is wide and smooth, and the ridging is of the same type as in the pedicle valve.

Dimensions.—Largest specimen (Plate LX, fig. 4):—

Length	37 mm.
Breadth	27 mm.

Medium-sized specimen (Plate LX, fig. 1*c–d*):—

Length	28 mm.
Breadth	21 mm.

Observations.—The valves appear to broaden and become smoother as the animal approached the adult and aged stages.

* Mem. Com. Geol. Russie, 1887, III, No. 3. t. 14, f. 21.
† Proc. R. Soc. Vict., 1903, XVI (n.s.), Pt. 1, pp. 74–75, t. 11, f. 2–4, t. 12, f. 7, 8.
‡ Foss. Pal. N. Galles du Sud, 1878, pp. 26, 84, 87 (Eng. Trans., pp. 66, 69).

I have been unable to find a description of any *Spirifera* closely resembling this form, which it is proposed to name in honour of Professor T. W. Edgeworth David, B.A., F.R.S.

Locality.—Brushy Hill, nine miles from Scone, near the Page River.

Horizon.—Carboniferous.

Collector.—C. Cullen.

Orthis (*Rhipidomella*) *valida*, sp. nov.

(Plate LX, figs. 2, 2*a–d*.)

This species, unfortunately known only in the condition of internal casts, occurs in great abundance at Rawdon Vale, near Gloucester. In spite of the impossibility of arriving at external characters at present, a new specific name is proposed, based on the general appearance of the internal structures.

The brachial valve was strongly convex, the pedicle to a lesser degree, and the outline, as in the case of most species of the section *Rhipidomella*, was sub-circular. The surface was evidently finely striate, and faint ridging is preserved on the marginal area of the inner surface.

Internal structure.—In the pedicle valve (Plate LX, fig. 2) the very pronounced flabellate diductor scars are well seen in part, and the ridge for adductor attachment was well marked, the pedicle muscle scar is also clearly seen; short hinge-line and small area. The dental processes were strongly developed.

In the brachial valve the characters of *Rhipidomella* are very noticeable. The cardinal process is very large and prominent (fig. 2*d*), and characteristically trifid, and the bases of the crural processes well developed. In fact, the structure of the processes of this portion of the valve appear to have been much more solidly developed than in any other species to which I have been able to refer. The cardinal process is much more elongate than in Hall and Clarke's figure of *Orthis* (*Rhipidomella*) *Penelope*, Hall,* and relatively more inflated. The adductor scars can be differentiated in two sets, but not so clearly as in the case of *R. australis*, McCoy.† The septal ridge is strongly developed. Hinge-line very short and area shallow.

This form can, in the case of internal casts, be readily distinguished from *R. australis*, McCoy, by the greater convexity and size, stronger muscle scars, lesser degree of differentiation of the adductor scars in the brachial valve, and more prominent cardinal and crural processes.

* Pal. N. York, VIII, Pt. 1, t. 6a, f. 10.

† Ann. Nat. Hist., 1847, XX, p. 234, t. 13, f. 4, 4a; Dun, Rec. Geol. Survey N. S. Wales, 1902, VII, Pt. 2. p. 79, t. 21, f. 10, 11 (for synonymy, &c.).

The specific name *valida* is proposed on account of the great strength of the internal processes.

Dimensions of largest specimen (Plate LX, fig. 2*b*) :—

Brachial valve.

Length	31 mm
Breadth	24 „
Depth	12 „

Locality.—Rawdon Vale, Portion 9, Parish Knowla, County Gloucester.

Horizon.—Carboniferous.

Collector.—G. A. Stonier, A.R.S.M.

XXXVI.—The Discovery of a Human Skeleton at Jenolan Caves: by R. ETHERIDGE, Junr., Curator of the Australian Museum, and O. TRICKETT, L.S., Inspector of Caves.

[Plates LXII and LXIII.]

THE skeleton discovered during exploration by Messrs. J. C. Wiburd, Caretaker, and J. C. Edwards, Senior Guide, is lying on the floor of a superficially small, but very lofty chamber, shown by survey to be about one hundred and thirty feet immediately under the Cathedral Cave, and sixty feet below the level of the Bone Cave, chambers of the Lucas series of caves, and at an approximate depth of three hundred and fifty feet from the surface.

The remains are lying anterior surface downwards, the portions of the skeleton present not actually in apposition, but approximately so. The bones visible on the cave floor appear to be :—

Portion of the left side of skull and face.
Inferior maxillary, or lower jaw.
Right and left humeri.
Left ulna and radius.
Portion of one of the scapulæ, or blade bones.
Small portion of the sternum.
Right and left femora.
Portion of the pelvis.
Mutilated sacrum.
Right tibia and fibula.
Portions of a few ribs.
Eight vertebræ, more or less perfect:

The bones are lying in a general direction of N. 25° E., and are spread over an oval space of seven feet three inches by three feet five inches, forming the actual channel of the chamber, which at this particular spot is stained a dark ochraceous brown, and is without crystalline formations of any kind, although a foot or two in advance of the head fragments the floor is brightly crystalline.

The bones are unencrusted, and firmly attached to the floor; indeed, a few are partially embedded in the latter. It is also quite possible that some of the missing members might be found by breaking the stagalmitic floor.

The bones of the left side of the skull and face still remaining are portions of the frontal and parietal, with the temporal crushed in, and parts of the malar and superior maxillary; these are in one piece. Contiguous to, but behind, is the inferior maxillary, or lower jaw, nearly entire, lying on the left ramus, which is slightly embedded in the floor; the right ramus projects upwards, and has its complement of teeth complete, but the condyloid processes are broken off. Hereabouts are brown-encrusted outlines resembling pieces of ribs. Behind again are portions of the bone which, from their solidity, appear to be parts of the pelvis, with the crushed sacrum. Radiating, or spread out from the latter are the femora, and nearly continuous with the right femur is its corresponding tibia and fibula. The bones of the hands and feet are not present.

The presentation of the posterior surfaces of most of the limb bones upwards induces the belief that previous to decomposition the body was lying front downwards. A calculation based on the length of the femora would indicate this to be the skeleton of a human being five feet ten inches in height, and the perfect ossification of the epiphyses and development of the teeth, that of an adult, in all probability a male, but in the absence of the pelvic details this point cannot be absolutely certain.

The important question whether or not these remains are those of a black must also remain an undecided one, but the development of the frontal prominence, the low and receding outline of the frontal bone, and the condition of such teeth as remain, induce us to regard them as those of an aborigine.

The chamber, which we venture to suggest may in future be known as the "Skeleton Cave," although superficially small, is of considerable height, approaching fifty feet. Previous to its discovery it was entirely cut off from all communication with any already-known cave.

Access to it was first obtained by passing through an opening west of the Lucas Bridge, thence leading along a rock-strewn and difficult passage to a second chamber, rather similar to, but smaller than, the Exhibition Cave itself, and at a lower level, which opens into an underground water-way. Following the latter north-westerly, a small opening was met with on the right, from which a passage was followed at an

upward angle for a distance of one hundred and twenty feet to the skeleton. The small opening was made by excavating the cave earth *in situ* and clearing away some stalagmitic matter connected with it.

The point to be emphasised, however, is that portions of this passage were completely blocked with red earth and débris, and it became necessary for Messrs. Wiburd and Edwards to excavate a way through such obstacles before the Skeleton Cave was revealed to them. These details are important in considering how the body of the unfortunate man found its way to the position now occupied by his osseous remains. It is hardly possible that he found his way there by the route in question previous to the blocking of the passages, and even supposing, for the sake of argument, that he did, the lapse of time between the two events must have been very long.

The rocky ceiling of the Skeleton Cave is pierced by several of the more or less circular holes common in our cave chambers, and around which some of the most beautifully-formed and glistening cascade formations are met with. In the present instance, two of these openings are at an oblique angle to the position occupied by the skeleton, and a third immediately above it. Below the former, large cascade formations lead down to the floor, and are partially active. One of the two holes is to all intents and purposes blocked with débris, the other is open and vent-like, and up it Guide Edwards ascended for some distance, only to find it ultimately similarly closed. The third opening, that immediately above the skeleton, is at present inaccessible, but it presents the appearance of being infilled in a similar manner. The extended, or spread-out, position of the bones is one that would result from a direct fall through such a hole, and we are of opinion that, lacking other evidence to the contrary, it was through one of these openings that the body was introduced into the Skeleton Cave, and in all probability through that immediately over it.

The walls of the Skeleton Cave, beyond the position occupied by the bones, come together, forming a high passage of a few feet in length, containing a fine canopy with a pool in the floor beneath it, and some excellent stalactites, ending in a precipice. The latter forms a portion of one of the sides of an enormous cavern, filled twenty-four feet below the precipice edge with water over thirty feet in depth, and forming a pool in the course of an underground channel. A branch of this runs westerly to a point near the Grand Archway, and contains a varied and beautiful series of "mystery" and other attractive formations. The part of the Lucas series of caves above described is five hundred feet in length, and, together with others recently discovered, covers a distance of half-a-mile.

The approximate age of the skeleton, geologically speaking, is, from its surroundings, naturally one of conjecture. We lack collateral evidence to guide us, such, for instance, as an association with the remains of our extinct marsupial

fauna. The cave earth and stalagmitic floors of Jenolan, unlike similar deposits at Wellington, have so far yielded no reliable trace of any member of this fauna, the few fragmentary bones hitherto so found not differing from those of recent species. On the floors of some of the caves wallaby and other small bones are scattered about in abundance, most of them encrusted with "formation," and all, as a rule, firmly cemented down. Bones of this description occur in front of the human skeleton.

All that can be said at present on this most interesting discovery, with any degree of certainty, is that—

(1) The skeleton is that of a human being.

(2) The bones repose on the floor of the cave, but whether or no any are entombed in the stalagmitic floor itself, there is no evidence to show.

(3) The bones are not encrusted with calcareous "formation."

(4) The bones are not accompanied by those of extinct marsupials.

(5) The body, previous to disintegration, possibly reached its final resting place from above.

(6) The Skeleton Cave is below the Cathedral Cave, approximately three hundred and fifty feet from the surface of the hill, and about twenty feet above an underground drainage channel.

We are, notwithstanding the absence of any data of geological or, perhaps, more correctly speaking, of palæontological age, impressed with the antiquity of these remains on physical grounds. The great lapse of time that must have accrued to enable the changes already outlined to have taken place since the introduction of the remains into the Skeleton Cave warrants us in this view.

It would have been impossible, in our opinion, for the individual to have voluntarily introduced himself into the cave in question, or any of those surrounding it, and in fact, if a black, it is almost certain he did not do so, from the well-known dread our aborigines entertain of all recesses from which the light of day is excluded.

Two possible instances to the contrary are, however, known—that of the mummified and partly stalactite-encrusted body in one of the Mosquito Plain Caves, near Mount Gambier, mentioned by the late Rev. J. E. T. Woods, and a child's skull found in a small cave at Bungonia.* Secondly, the "bones of the extremities" found in No. 2 Cave at Wellington, and reported by the late Mr. G. Krefft, can hardly be considered in the same category as the skeleton found by Messrs. Wiburd and Edwards, for there is reason to believe that the former were casually washed in from the surface, and were only recent bones.†

* Etheridge—Rec. Geol. Survey N. S. Wales, 1893, III, Pt. 4, p. 131.
† Etheridge—Proc. Linn. Soc. N. S. Wales, 1890, V (2), p. 264.

PLATE LI.

Fig. 1. Columnar sandstone at the head of navigation, Lane Cove River, showing curved prisms, and the sharp transition to unaltered rock.

Fig. 2. The same occurrence showing the fan-like disposition of the columns.

G. W. Card, photo.

FIG. 1.

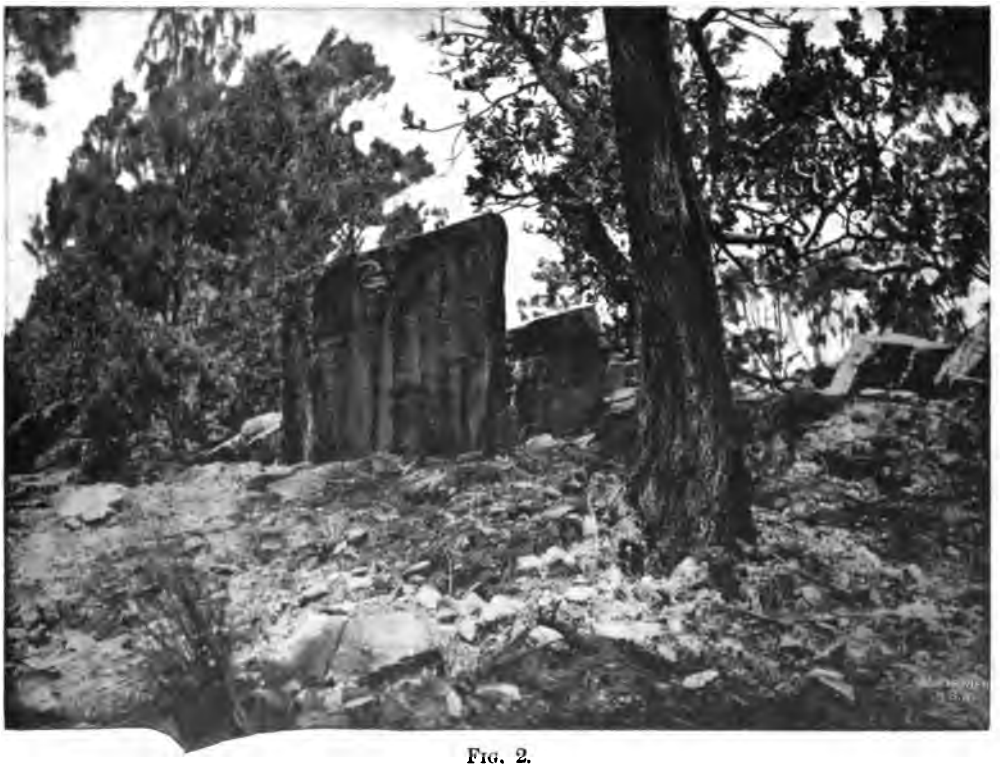


FIG. 2.

PLATE LII.

Fig. 1. Decomposed dyke with well developed columns of sandstone on one side, Government Quarry, near Dural.

Fig. 2. Columnar sandstone, showing the abrupt termination of the columns, Government Quarry, near Dural.

L. F. Harper, photo.

FIG. 1.

FIG. 2.

PLATE LIII.

Cliffs at Bondi, showing :—

(*a*) Decomposed dyke transversing Hawkesbury sandstone.

(*b*) Columnar structure, not in contact with the dyke

(*c*) The fan-like disposition of the columns.

(*d*) False bedding and weathering of the sandstone.

G. W. Card, photo.

PLATE LIV.

Quarry in volcanic neck, Minchinbury, Rooty Hill.

L. F. Harper, photo.

PLATE LV.

The even sky-line of the Stannifer (or "post-basaltic") level near Wilson's Downfall, as seen across the Marylands and Koreelah River from the Watershed of Cullen's Creek and the Tooloom River. Height of plateau, 3,000—3,200 feet.

PLATE LV

PLATE LVI.

Fig. 1. The general appearance of the Mole Peneplain, with remnants of the Bolivia level. Point of view.—Little Bolivia Hill (4,000 feet).

Fig. 2. Even sky-line of the Mole Peneplain (about 3,650 feet). From Ottery Hill, near Emmaville.

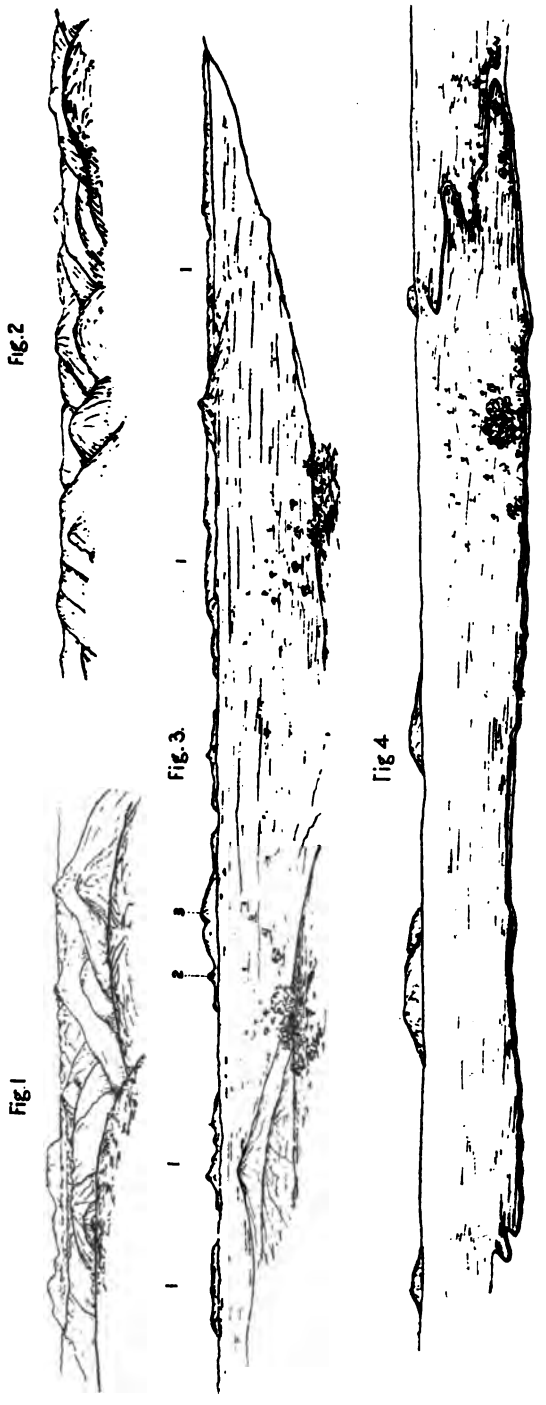
Fig. 3. General appearance of the plain (3,200 feet), formed by post-basaltic gradation with residuals of Bolivia and Capoompeta levels in distance. Taken from Ottery Mines.

1 .. .. .. Bolivia level.

2 .. .. .. Spiriby (5,100 feet).

3 .. .. .. The Magistrate (5,100).

Fig. 4. Plateau cycle plain (2,800 feet). Seen from Tingha.



39811

Photo-lithographed by
W. A. Gullick, Government Printer,
Sydney, N.S.W.

PLATE LVII.

Barraba meteorite.

Fig. 1. Residue insoluble in HCl (1 : 3).
The columnar structure of the Kamacite (?) will be noticed on the extreme right and near the middle left of the figure.

Fig. 2. Symmetrical markings on a plate picked out from the insoluble residue. Highly magnified.

Photo. mic., T. Whitelegge, Australian Museum.

FIG. 1.

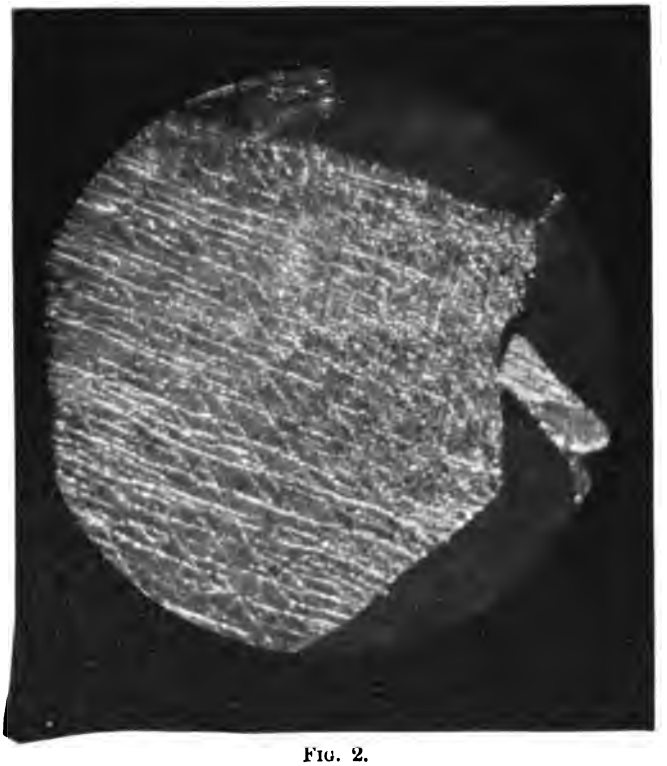


FIG. 2.

PLATE LVIIA.

The Barraba Meteorite.

H. Barnes, Australian Museum, photo.

PLATE LVIII.

Glossopteris nephroeidicus, *sp. nov.*

PLATE LIX.

Fig. 1. Glossopteris nephroeidicus, *sp. nov.*

Fig. 2. „ „ Venation, magnified.

Fig. 3. Verticil of leaves of Glossopteris, x 2.

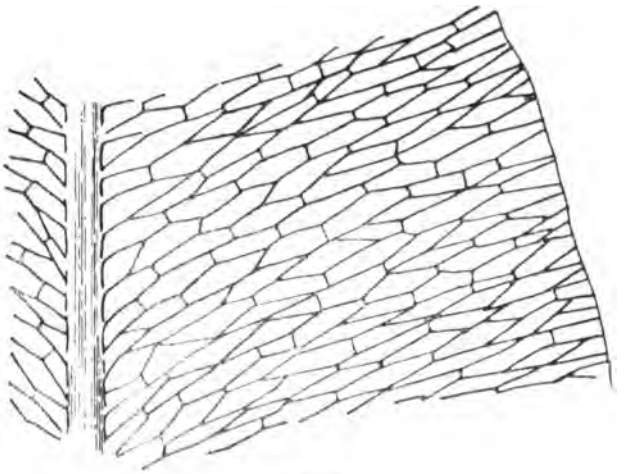


FIG. 2.

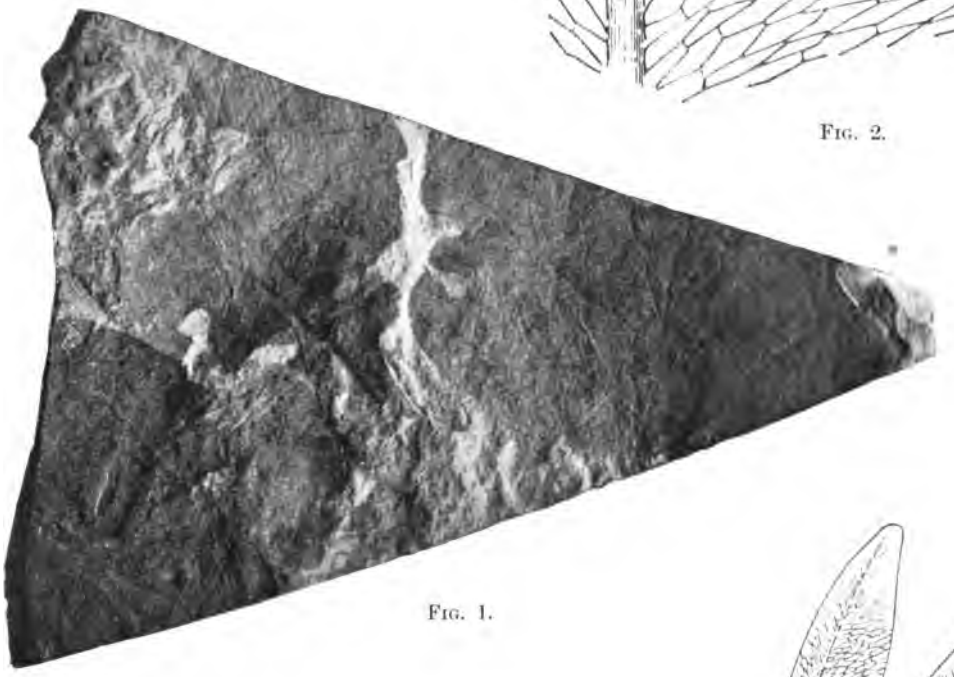


FIG. 1.

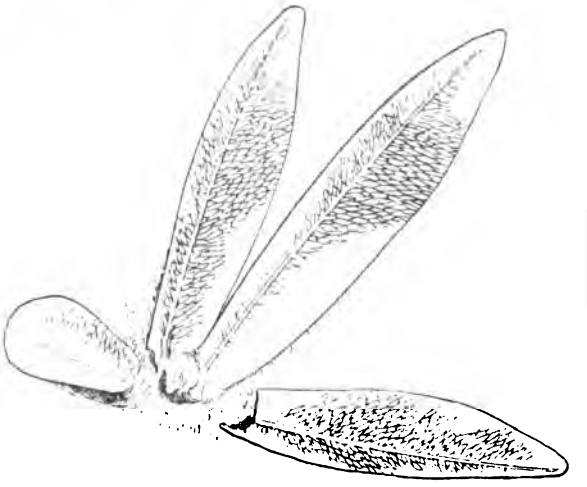


FIG. 3.

PLATE LX.

Spirifera Davidis, sp. nov.

Fig. 1. Cast of interior of pedicle valve with portion of matrix remaining, showing relative thickness of umbonal region of valve.

1*a*. Internal cast of pedicle valve, showing the undifferentiated adductor and diductor area.

1*b*. Internal cast of pedicle valve, showing front view of umbonal portion.

1*c*. Slightly distorted specimen, showing the brachial valve, with well-marked fold, ribs, and inconspicuous area of pedicle valve.

1*d*. Same specimen, showing the sinus, and general contour.

1*e*. Weathered specimen, showing the relative convexity of the two valves, and the well-developed crural plates.

1*f*. Imperfect pedicle valve of the largest specimen known.

Orthis (*Rhipidomella*) *valida*, sp. nov.

Fig. 2. Internal cast of pedicle valve showing the upper portion of diductor scars, the position of the well-marked pedicle scar, and the cavities representing the position of the teeth.

2*a*. The same specimen, viewed laterally, showing the great convexity of the brachial valve.

2*b*. The internal cast of the brachial valve of a large specimen, showing the prominent cast of the adductors and the considerable space left by the removal of the thick cardinal process.

2*c*. The same specimen viewed from the side, showing the faint line of separation between the anterior and posterior adductors, the strong convexity, and the great prominence of the casts of the adductor scar areas.

2*d*. Mould of internal cast of the brachial valve of another specimen, showing the strong, low, cardinal process, the short crural plates, and the adductor scars.

Drawn from nature by F. R. Leggatt.

1

1a

1b

1c

1d

1e

1f

2

2a

2b

2c

2d

F. R. Leggatt, del.

PLATE LXI.

Chonetes Culleni, sp. nov.

Fig. 1. Imperfect pedicle valve, showing five spines on one side of the beak.

1*a*. Portion of inner surface of brachial valve, showing broad, bifid cardinal process, raised anterior muscle area, median septum, and brachial ridges. x 2.

Cyrtina wellingtonensis, sp. nov.

2. Brachial valve, showing well-marked median fold. x 2.

2*a*. Area of pedicle valve of same specimen, showing—through the upper uncovered portion of the delthyrium—the median septum. x 2.

2*b*. Pedicle valve of another specimen, showing well-marked median sinus and laminar growth lines. x 2.

2*c*. Cardinal area of subject of fig. 2*b*, showing the striate character of the area—foramen almost at apex of delthyrium. x 2.

Meristina (?) *australis*, sp. nov,

3. Brachial valve showing adpressed condition of beaks.

3*a*. Pedicle valve showing faintly folded sulcus.

3*b*. Same specimen, viewed posteriorly, showing well-marked sinal tongue.

3*c*. Lateral view.

3*d*. Young individual, showing lesser convexity of brachial valve.

3*e*. Specimen with portion of brachial valve removed, showing crystalline replacement of spiral areas.

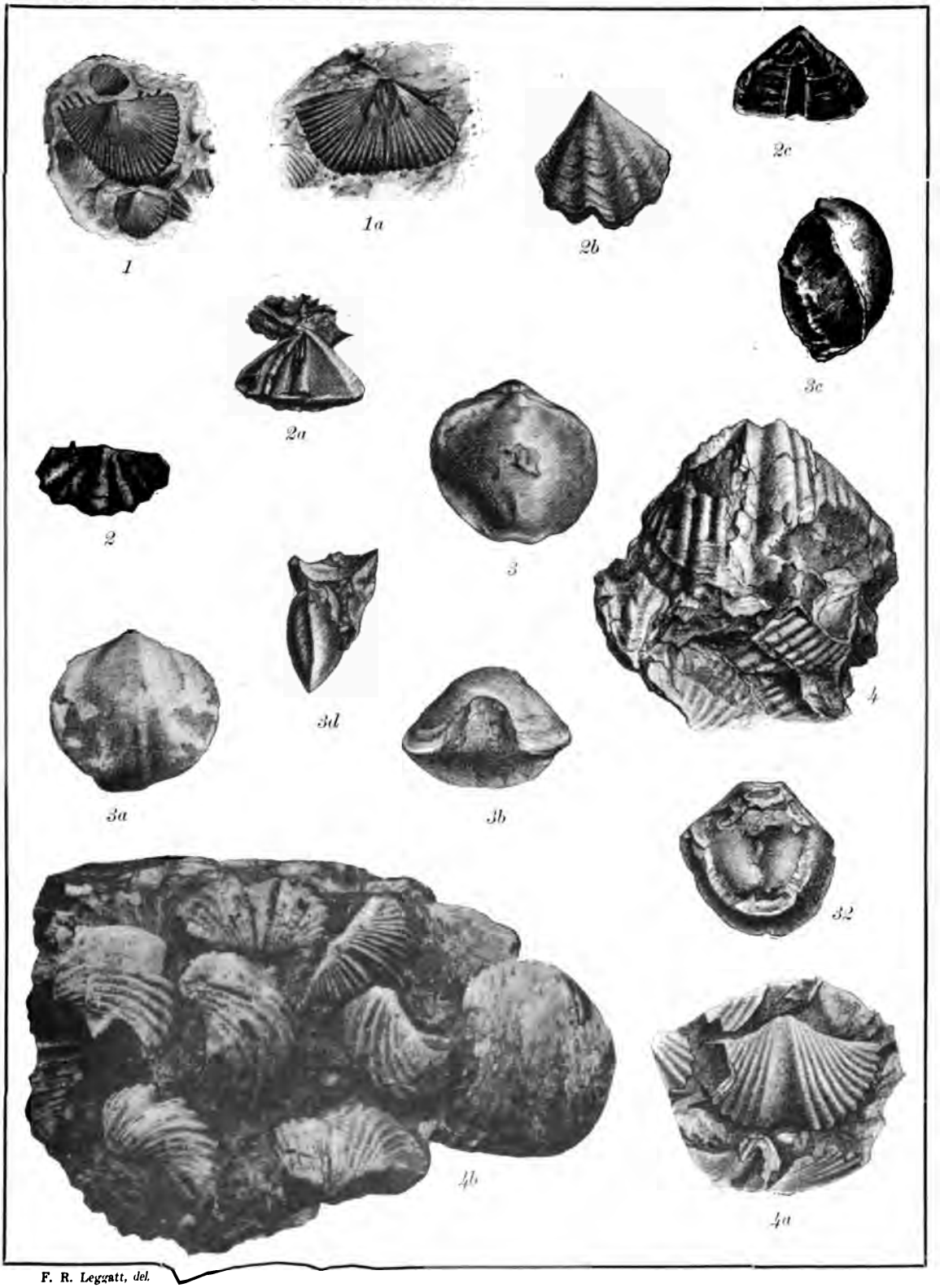
Spirifera Pittmani, sp. nov.

4. Pedicle valve of largest specimen.

4*a*. Pedicle valve of younger individual. It must be noted that much of the shell is covered by matrix, so that the true outline is not seen.

4*b*. Photograph of a specimen showing individuals in different stages of growth.

Drawn from nature by F. R. Leggatt.



F. R. Leggatt, del.

PLATE LXII.

Remains of Aboriginal skeleton—Jenolan Caves.

O. Trickett, Photo.

PLATE LX.

Spirifera Davidis, sp. nov.

Fig. 1. Cast of interior of pedicle valve with portion of matrix remaining, showing relative thickness of umbonal region of valve.

1*a*. Internal cast of pedicle valve, showing the undifferentiated adductor and diductor area.

1*b*. Internal cast of pedicle valve, showing front view of umbonal portion.

1*c*. Slightly distorted specimen, showing the brachial valve, with well-marked fold, ribs, and inconspicuous area of pedicle valve.

1*d*. Same specimen, showing the sinus, and general contour.

1*e*. Weathered specimen, showing the relative convexity of the two valves, and the well-developed crural plates.

1*f*. Imperfect pedicle valve of the largest specimen known.

Orthis (*Rhipidomella*) *valida*, sp. nov.

Fig. 2. Internal cast of pedicle valve showing the upper portion of diductor scars, the position of the well-marked pedicle scar, and the cavities representing the position of the teeth.

2*a*. The same specimen, viewed laterally, showing the great convexity of the brachial valve.

2*b*. The internal cast of the brachial valve of a large specimen, showing the prominent cast of the adductors and the considerable space left by the removal of the thick cardinal process.

2*c*. The same specimen viewed from the side, showing the faint line of separation between the anterior and posterior adductors, the strong convexity, and the great prominence of the casts of the adductor scar areas.

2*d*. Mould of internal cast of the brachial valve of another specimen, showing the strong, low, cardinal process, the short crural plates, and the adductor scars.

Drawn from nature by F. R. Leggatt.

1

1a

1b

1c

1d

1e

1f

2

2a

2b

2c

2d

F. R. Leggatt, del.

Date Due

3 2044 102 944 493